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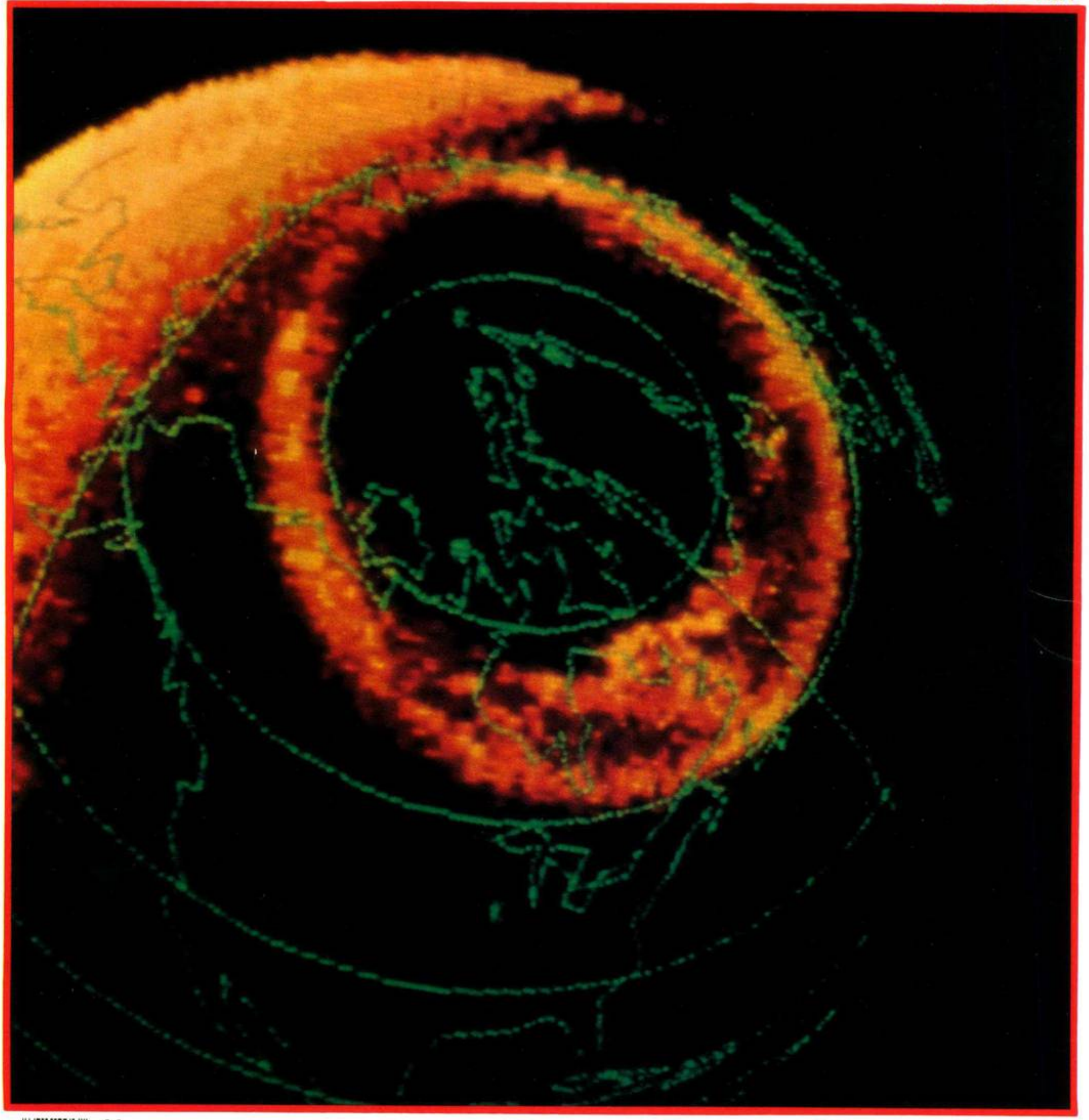

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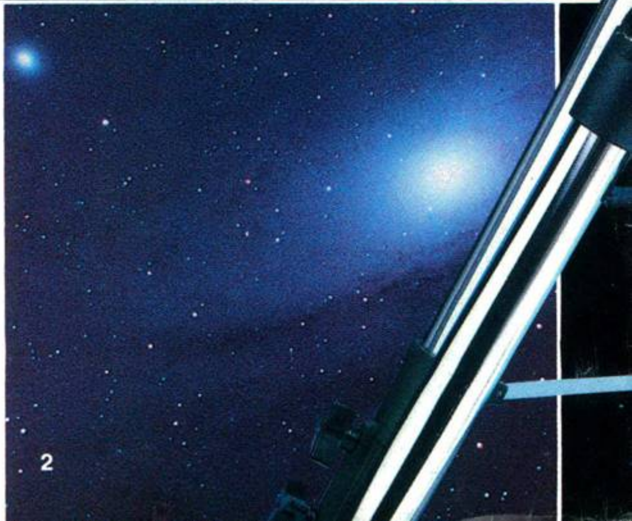

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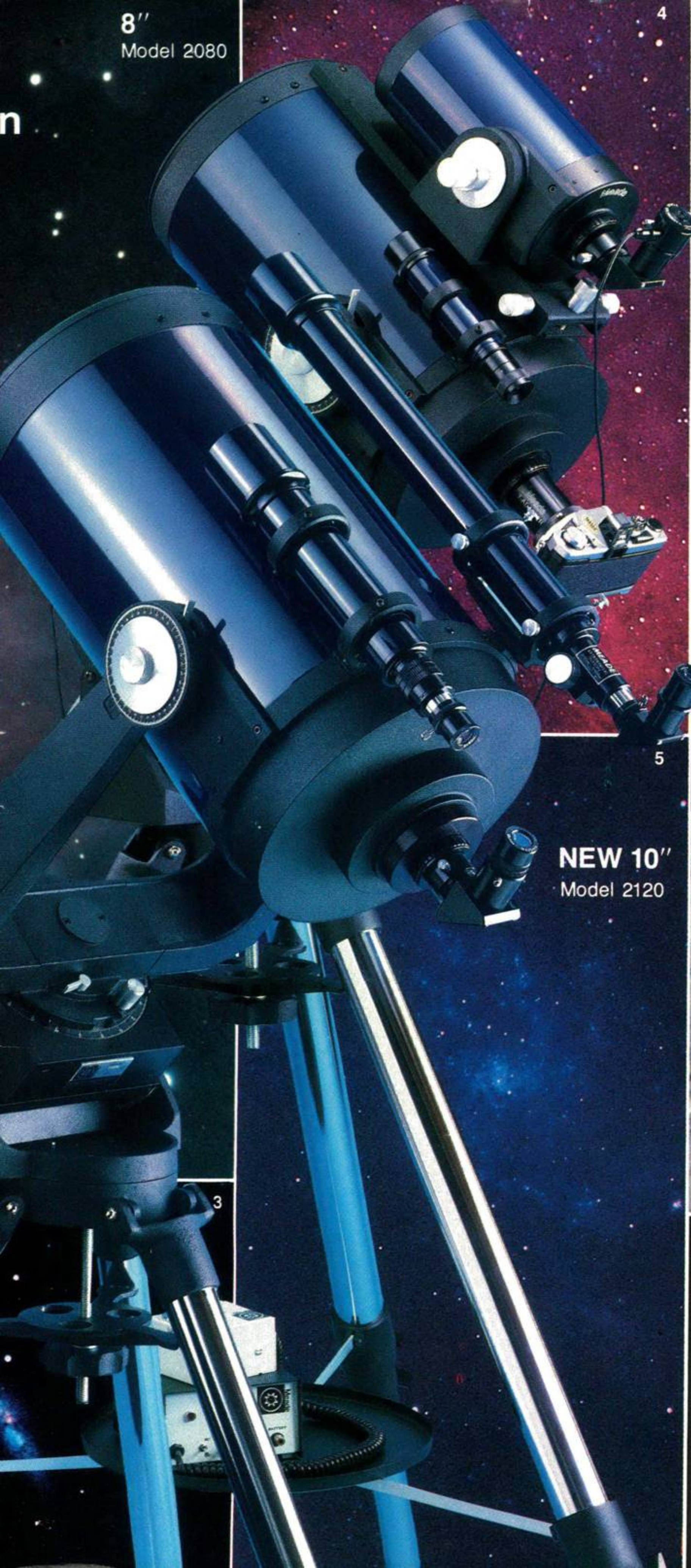

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All astrophotographs shown on these pages were taken through off-the-shelf, unmodified Meade 8″ Model 2080 Schmidt-Cassegrain telescopes. For further technical details on these and many other astronomical photographs, send for your free copy of the Meade Schmidt-Cassegrain Astrophoto Brochure. (Alternately, the complete Meade 52-page General Catalog is available at $3.00 by First Class Mail and includes the Astrophoto Brochure at no additional charge.)

Key to Photographs
1, 2, 3, 5—Leo Henzl; **4, 7**—Emery Hildebrand; **6**—Paul Roques; **8**—John Sanford

1. Orion Nebula M42; exposure time 50 mins. **2.** Andromeda Galaxy M31; 60 mins. **3.** Galaxy M82; 60 mins. **4.** Milky Way in Sagittarius (50mm piggyback photo). **5.** Spiral Galaxy M33; 75 mins. **6.** Spiral Galaxy M51; 90 mins. **7.** Omega Nebula M17; 40 mins. **8.** Moon—Clavius region.

ASTRONOMY

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Cover: Intense showers of charged particles funnel down Earth's magnetic field to create an oval of aurora around the northern polar cap of our world. This month, ASTRONOMY examines the cause of the aurora and the intimate ties between Earth and Sun. Dynamics Explorer satellite image. These pages: Constellations of the northern sky shine through the red aurora, a ruddy light from excited oxygen atoms more than 100 miles above Earth's surface. Photo by Bill Iburg.

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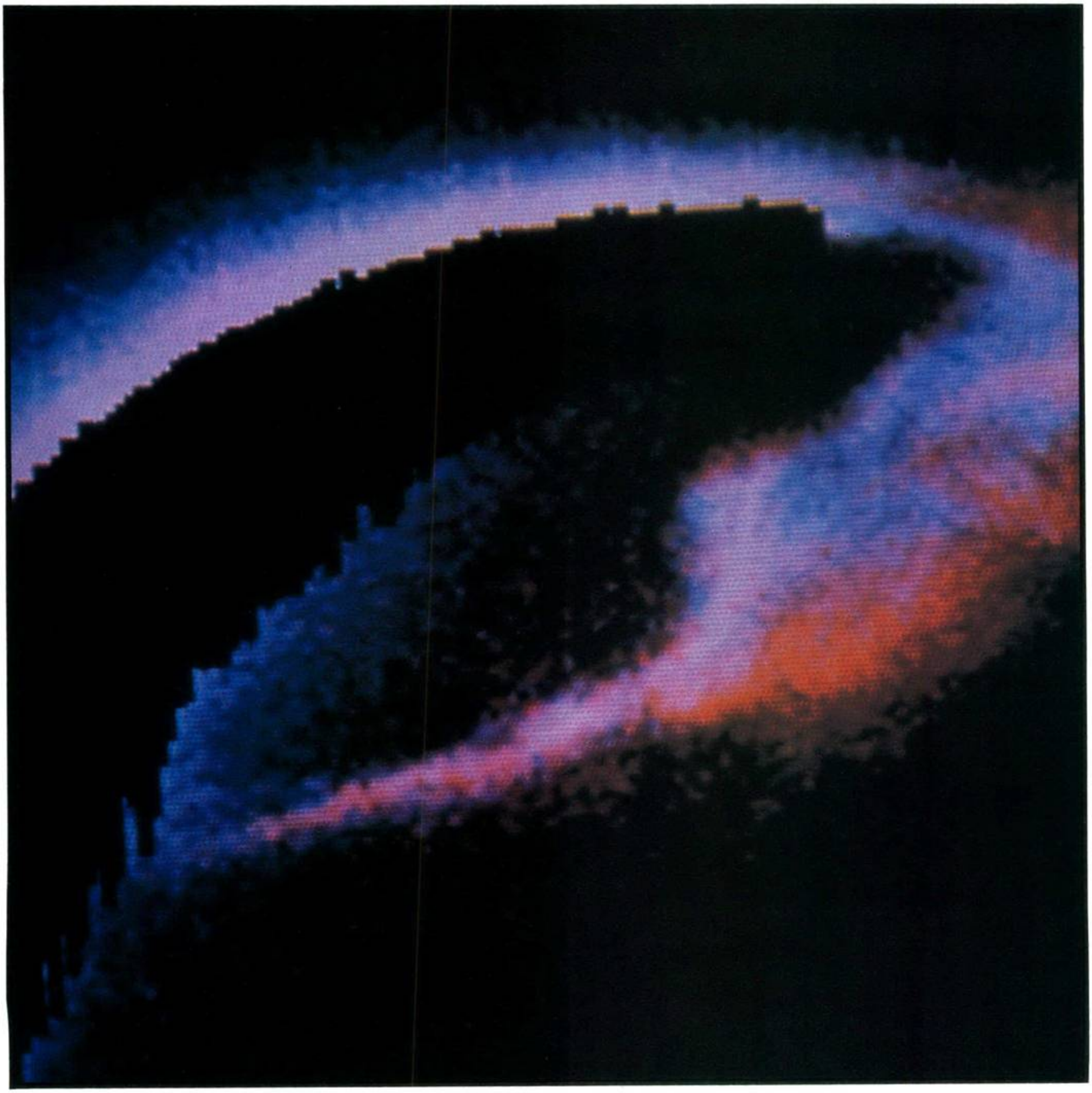
Celestial Winds

Polar Lights

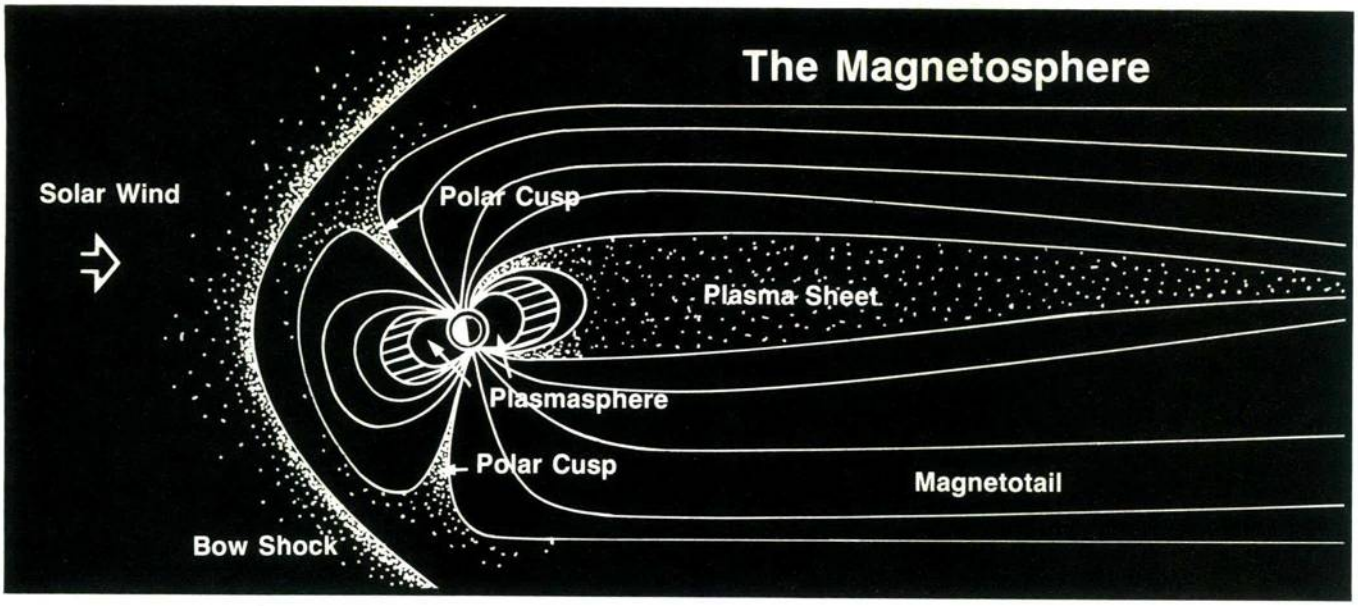
by Francis Reddy

From space, our planet looks small and fragile, incapable of dealing with the powerful forces surrounding it. Nothing could be further from the truth.

Previous page: A fading aurora illuminates the terrestrial evening sky. Three hours after our cover photo, ultraviolet light from ionized oxygen atoms on the nightside hemisphere still rivals the dayside intensity, but the sunward portion of the auroral oval shows no significant emission. Below: Aurora extends from the mid-Atlantic Ocean to the western coast of Norway in this true-color composite image taken nearly a planetary diameter above Earth. Scattered sunlight illuminates the limb of our planet above the dayside atmosphere.



Photos courtesy Lou Frank, University of Iowa



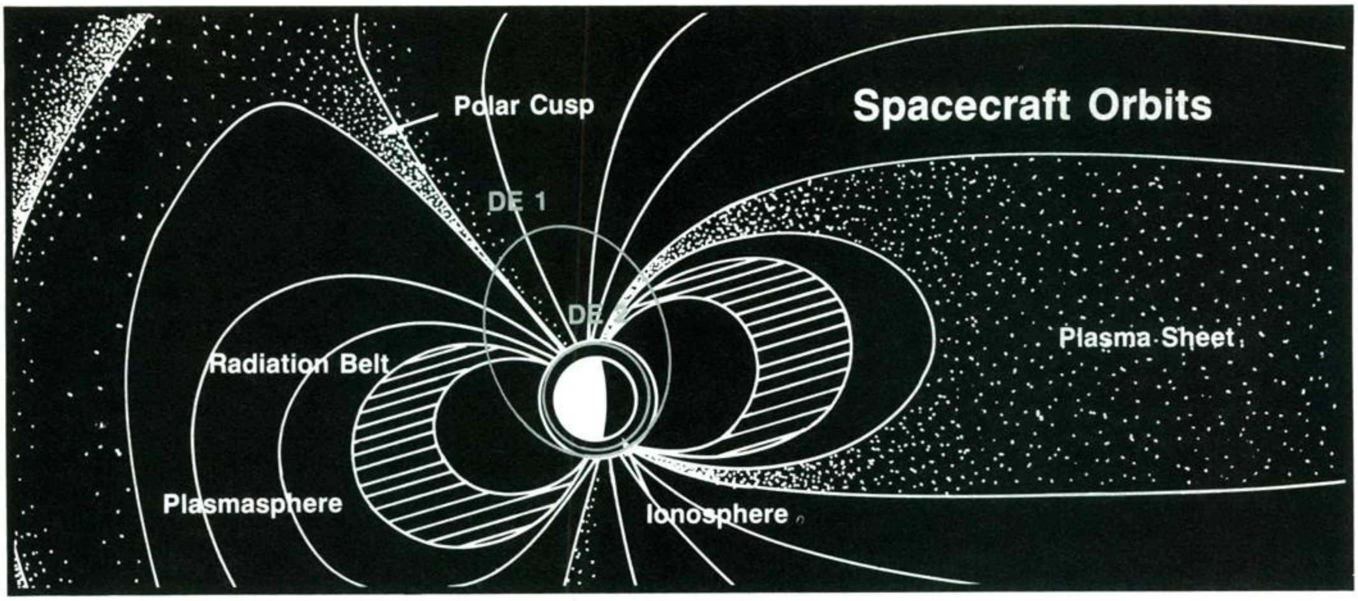
Together, Earth and Sun create an invisible shield that envelops our planet — a magnetic bubble in the stream of electrically charged particles that makes up the interplanetary medium. Called the *magnetosphere*, this cavity is a complex region of intense electric currents, intertwined magnetic fields, and ionized gases. The most visible manifestation of this dynamic activity is the aurora, but charged particles in the magnetosphere can also interfere with high-frequency radio and television signals (occasionally to the point of complete blackout), damage satellite electronics, and cause large-scale electrical failures by tripping the protective circuit breakers of power transmission lines. Even oil companies have an interest in the magnetosphere — electric fields induced by aurora may accelerate corrosion effects that lead to the rupture of pipelines. And as if that weren't enough, there is strong evidence for a link between magnetospheric activity and the occurrence of long-term droughts and other changes of weather and climate.

Ever since the discovery of the Van Allen belts by Explorer 1 in 1958, scientists have been piecing together the dynamics and composition of the magnetosphere — a project that begins at the center of the Earth. Liquefied metals in our planet's central core produce electric currents as they circulate. These changing currents generate a magnetic field. The solar wind, a stream of ionized gases shot from the Sun, slams into the Earth's magnetic field at 500 kilometers per second and distorts it from the dipole form of a simple magnet. As it sweeps past, the solar wind drags magnetic field lines along with it — those on the Earth's sunward side become compressed, while others are swept back behind our planet. This stream of solar particles molds the planetary magnetic field into a comet-shaped, elongated cylinder that points away from the Sun. Stretched field lines form a *magnetotail* that extends behind our planet well beyond the Moon's orbit. On the sunward side is the *bow shock*, the blunt-nosed outer boundary of our magnetic shield some 60,000 km away.

A variety of fates await those solar particles that make their way through the bow shock and into the magnetosphere. Some move out to the far end of the magnetotail, flow into it, and are stored as a layer of plasma within it. Convulsions of this *plasma sheet* shoot charged particles down toward the Earth, creating magnetic storms and the nightside aurora. Other solar wind particles stream into holes on the magnetosphere's sunward side, called the *polar cusps*, and converge on the polar regions of Earth to generate the dayside aurora. Still others may find their way into a rotating, doughnut-shaped storage ring of low-energy plasma. This region, called the *plasmasphere*, extends out to five times the Earth's radius and encloses the famous Van Allen radiation belts, which contain temporarily trapped high-energy solar wind and cosmic ray particles.

It seems obvious that sending instruments up into the magnetosphere is the only proper way to examine its structure. Unfortunately, the rapid orbital motion of satellites and the fact that satellite instruments detect only effects in their immediate vicinity make it difficult to determine whether the changes they measure are local or widespread. Ideally, investigations of our planetary environment should coordinate measurements from several satellites with ground-based observations of the aurora. The latest magnetospheric probes, Dynamics Explorers 1 and 2, did just that.

"For the first time," says Valerie Neal, a reasearch assistant at Essex Corporation, "we can look at the aurora from above and below simultaneously." Spacecraft have photographed the aurora before, but the eccentric polar orbit of Dynamics Explorer 1 takes its cameras out to 3½ times the Earth's radius, or about 22,000 kilometers — ten times higher than any comparable imaging instruments. At this altitude, the spacecraft sees the whole glowing Earth and can monitor the entire region of auroral activity, the *auroral oval*, for as long as five hours. Dynamics Explorer 2 was launched into a more circular, low-altitude orbit, but the plane of its orbit was identical to that of its eccentric twin; the two satellites frequently lined up over the same area on Earth. These alignments provided scientists with simultaneous observations from different heights. Remarks Neal, "We could see what went into the atmosphere from space and watch what came out of it on the ground."



The spacecraft revealed a region even more complex than previously thought. For example, the satellites discovered an entirely unsuspected form of the aurora. They also discovered fountains of ionized gases — "polar winds" — flowing *up* into the magnetosphere from Earth. Before this mission, researchers believed that the dominant source of magnetospheric plasma was the solar wind.

Before the age of satellites, only the aurora's glow hinted at the existence and structure of the magnetosphere. By 1958, it was clear that the aurora was caused by showers of protons and electrons entering the atmosphere. Somehow, these charged particles are injected into the Earth's polar atmosphere at high velocity. There they strike neutral gas atoms, and the collisions cause the atoms to fluoresce. Each gas emits its own characteristic radio, infrared, ultraviolet, and X-ray radiation. What we observe as the aurora is visible light emitted by excited atmospheric gas.

Rocket probes launched into aurorae during the International Geophysical Year in 1958 revealed that energetic electrons were the particles most involved in the atmospheric bombardment. Even a moderate aurora needs around one billion electrons per square centimeter each *second*, with an average speed for the particles of 20,000 kilometers per second! Protons also create an aurora, but one far weaker than that generated by electrons. Over an area of similar size, a bright electron aurora dumps as much as 100 times the energy of a proton aurora.

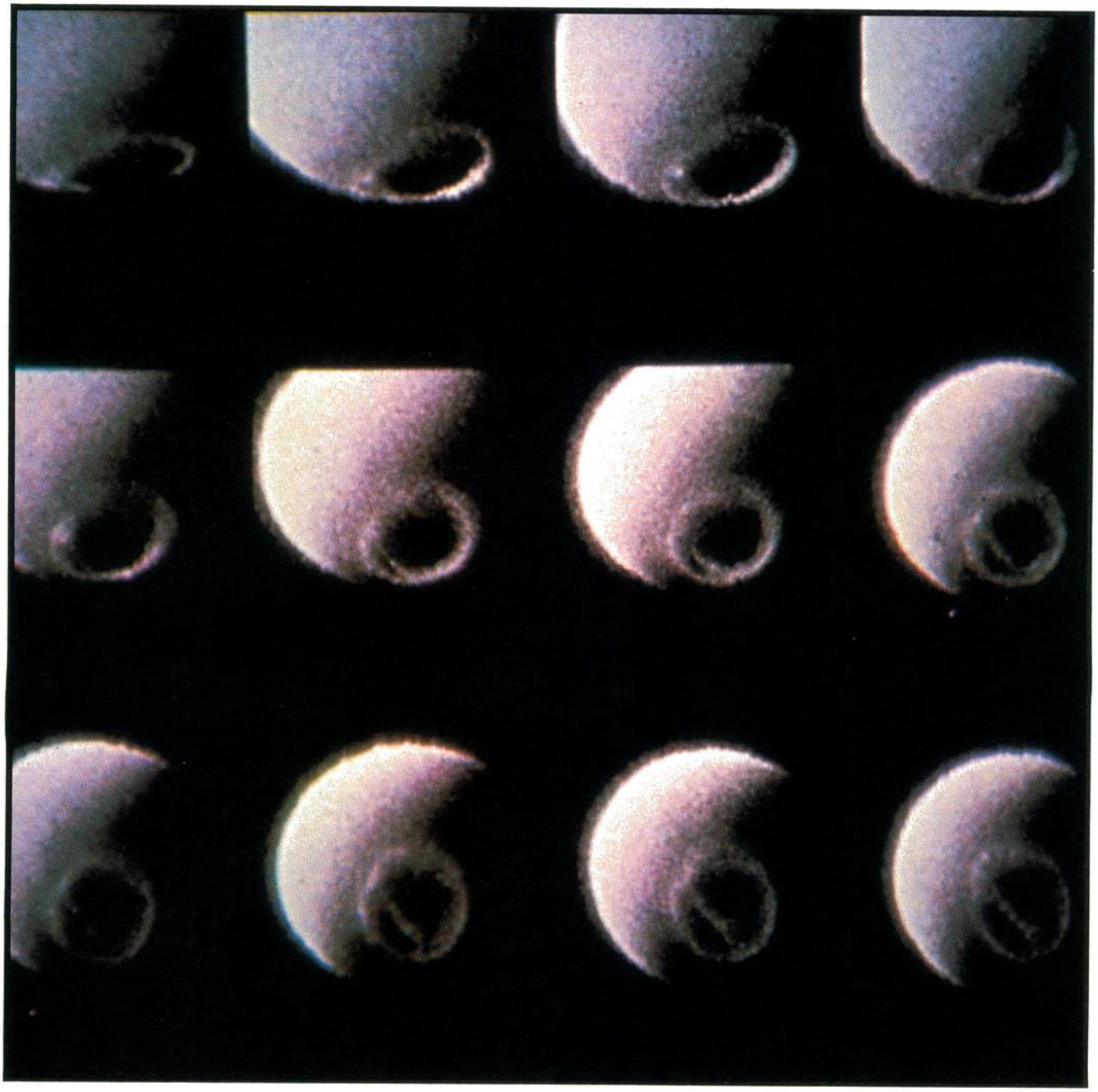
In 1963, Soviet geophysicists showed that the aurora occurs in an oval band centered on the Earth's magnetic poles (as opposed to the geographic or rotational poles). This auroral oval is more or less fixed in space, so the position of an area on Earth relative to the oval changes as the Earth rotates underneath it. It is easier for charged particles to spiral down magnetic field lines than to cross them, and the lines of Earth's magnetic field converge at the geomagnetic pole. Electrons rush down this converging portion of the magnetic field, generating aurora at altitudes between 95 and 240 kilometers as they strike atmospheric gas. In essence, the auroral ovals mark the edge of an "electron funnel" formed by the converging lines of Earth's magnetic field. Although the auroral ovals are usually about 4,500 kilometers across, changing conditions in the magnetosphere can drastically alter their size.

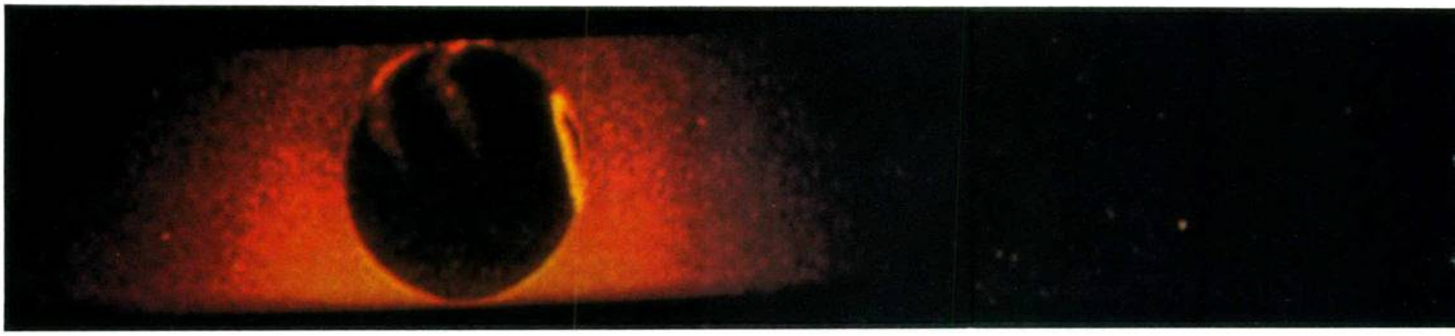
One of the surprises from the Dynamics Explorer mission was a previously unknown form of the auroral oval. In one series of images, the spacecraft's cameras watched as an auroral bar evolved within the oval. "Generally, it's a more or less straight arc that crosses the entire auroral oval," notes Lou Frank of the University of Iowa. This "theta" configuration appears to be intimately related to the formation of the auroral oval during magnetic storms. The theta arc frequently forms in the center of the oval, but can develop on the edge and rapidly center itself over the polar cap.

So far, no one knows how the theta shape arises. According to measurements made from Dynamics Explorer 2, the particles forming the auroral bar are no different from those that create the oval. "This gives us a clue, but not a solution," says Frank. "Somehow we have to re-structure the magnetotail." Physicists believe that a neutral layer separates "north" and "south" portions of the plasma sheet, splitting Earth's magnetotail in two. This picture easily accounts for the auroral ovals, but not for the theta arc. Since the bar always cuts the auroral oval on the line joining Sun and Earth, some researchers have suggested that the magnetotail may actually divide once again under certain conditions. This second division might create an "east-west" split down the length of the plasma sheet, somehow enhancing the electron flow along the Sun-Earth line. "Right now," adds Frank, "no one has any idea of how this might be accomplished."

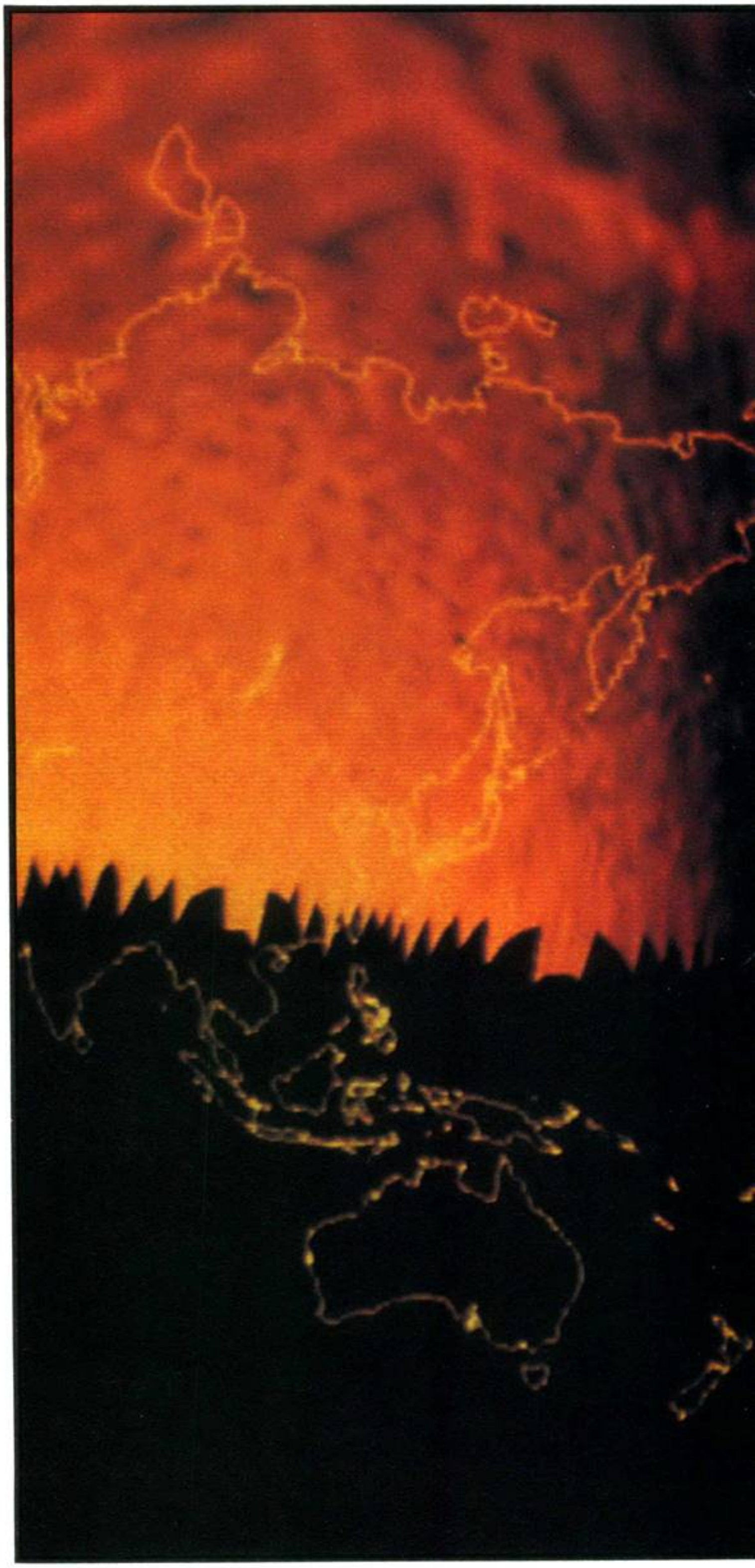
Until the late 1960s, physicists believed that most of the trapped plasma in the magnetosphere came from the solar wind. How, then, do these particles enter the magnetosphere? And why are they directed to the Earth's poles? Only a few percent of the solar wind particles impinging on the magnetosphere manage to get into it, and many of these are funneled down the polar cusps and into the dayside atmosphere. But what about the nightside?

In this sequence of images taken 12 minutes apart, a new auroral configuration unfolds. The spacecraft, heading toward apogee on the outward leg of its orbit, reveals an arc *within* the auroral oval (fifth image). With each step in the sequence, the "theta" shape becomes progressively more evident as the arc moves toward the center of the polar cap. This configuration remained stable for at least another 2½ hours.





Above: A slice of the ultraviolet sky — a single panorama 30° wide — was created when Dynamics Explorer I passed into Earth's shadow. Lit by its own auroral fires, our planet floats in space, silhouetted against the diffuse glow of solar radiation scattered by Earth's exosphere of atomic hydrogen. Scanning northward, the strange terrestrial lights give way to the few hot stars near the North Celestial Pole. A portion of the galactic plane appears in the south, revealing a belt of hot ultraviolet stars that includes the star cluster associated with θ Carinae.

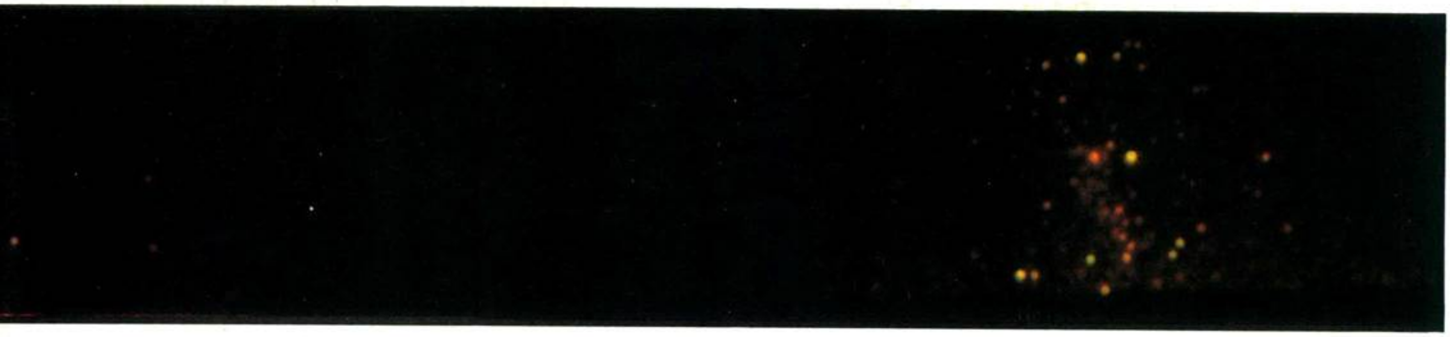


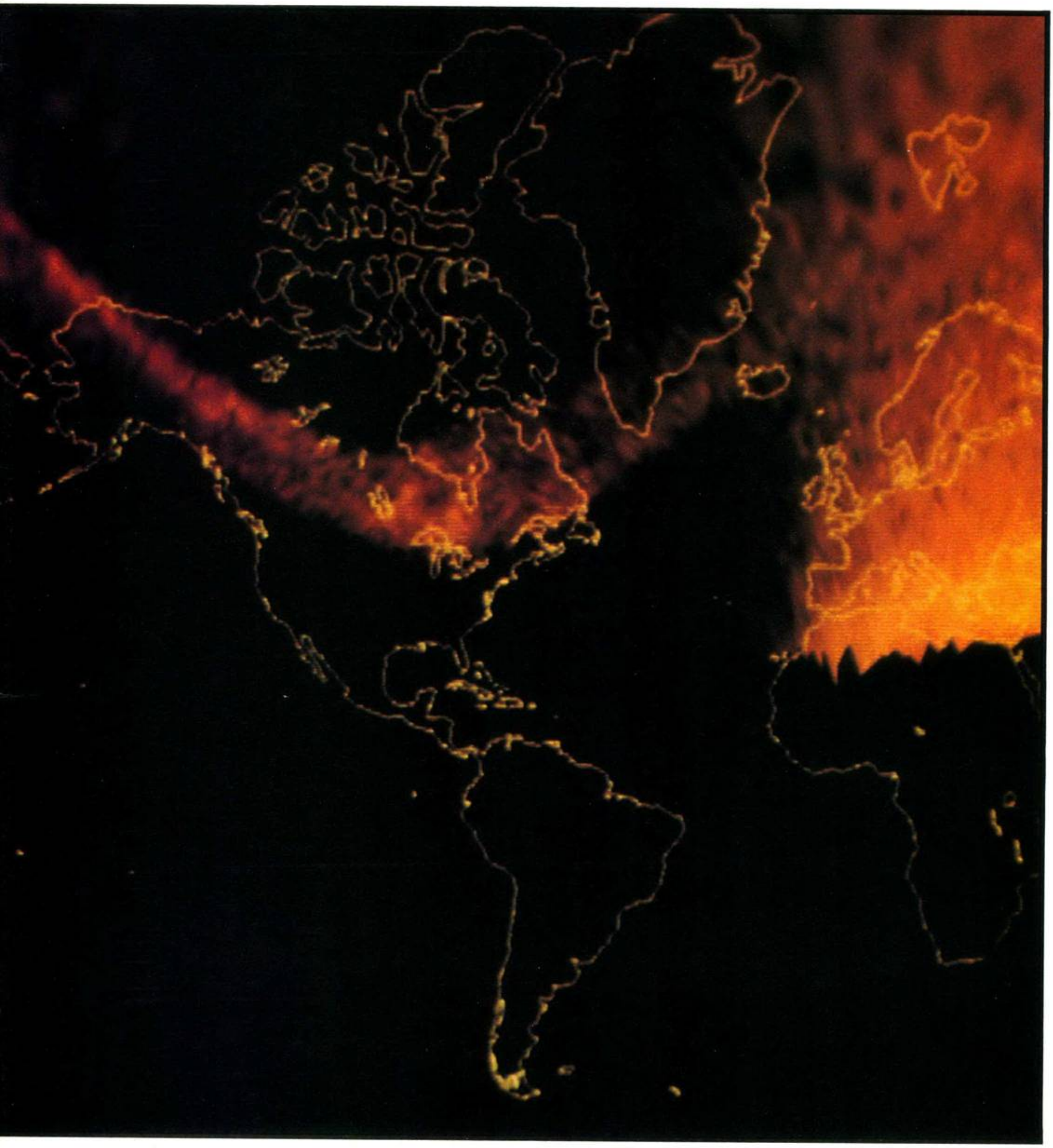
Right: Coast lines add scale to ultraviolet data replotted on a Mercator map. The active aurora extends across the night hemisphere and into the sunlit portion. Variations in scattered solar radiation, possibly caused by turbulent atmospheric cells 120 kilometers high, may account for the mottled appearance of the dayside hemisphere. Earth's limb, viewed from the spacecraft's polar location, is roughly 30° north latitude.

The solar wind carries magnetic field lines from the Sun in addition to its high-energy electrons and atomic nuclei, and some of these embedded field lines actually merge with the terrestrial magnetic field. Thin layers of charged particles work to keep solar and terrestrial magnetic fields apart, but instabilities in the plasma flow allow bundles of field lines to connect.

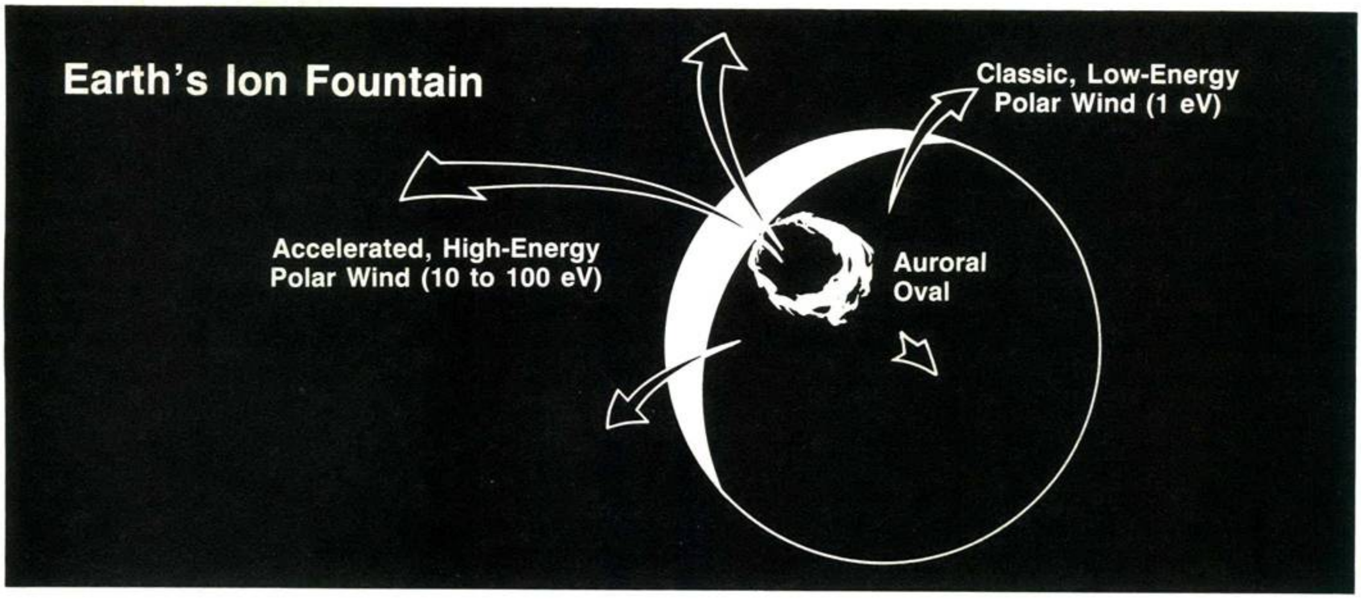
Plasma blows across the region where magnetic fields merge, electrons moving in one direction and positively charged particles moving in the opposite direction. Separating the positive and negative charges sets up a potential difference of 50,000 volts between the morning and evening sides of the plasma sheet. Electrons move toward the positively charged side of the plasma sheet, driving electrical currents measuring tens of millions of amperes around the magnetosphere's outer layer. Most of the loops of electrical current join in the middle of the plasma sheet at the far end of Earth's magnetotail. Near our planet, however, the magnetic field lines converge on the polar regions, forming our electron funnel. The magnetospheric current drives electrons down the funnel into one side of Earth's atmosphere, out the opposite side, and back into the plasma sheet — completing a circuit and generating the auroral ovals.

There are other ways for particles to enter the atmosphere. In 1964, Syun Akasofu of the University of Alaska noticed that the steady, quiet glow of an aurora





An auroral curtain snakes across the sky as seen from a more familiar perspective — the surface of our world. Photo by Forrest Baldwin.


Earth's Ion Fountain
Classic, Low-Energy Polar Wind (1 eV)
Accelerated, High-Energy Polar Wind (10 to 100 eV)
Auroral Oval

may suddenly become very active. He called this sudden activation of a quiet aurora into a bright, spectacular display an auroral *substorm*. During active magnetic conditions, substorms can occur every few hours. Substorms reach their peak in about 10 minutes and gradually subside, but the rapidly moving aurorae they create can induce surges of electrical current in long conductors — like electrical power grids or oil pipelines.

Substorms occur when conditions allow a particularly strong merging of solar and terrestrial magnetic fields. Field lines bend back behind Earth and pinch the material in the plasma sheet. Compression increases until the pinched section of the plasma sheet is unable to tolerate further increases. North and south field lines merge in the center of the plasma sheet, but this forced connection is very unstable. Although the details of the process are still unknown, the accumulated magnetic energy is somehow transformed into kinetic energy, squirting high-velocity plasma toward Earth.

In the past, instruments launched into the magnetosphere were capable of measuring only particles with high energies, such as the hydrogen and helium nuclei of the solar wind. In 1970, improved instrumentation led to the discovery of high-energy oxygen atoms missing only one electron. But particles shot from the Sun lose more than one electron. The discovery of singly ionized oxygen suggested that at least some constituents of the magnetosphere must come from the Earth's ionized upper atmosphere. "Then the question changed," remarks Rick Chappell of NASA's Marshall Space Flight Center. "Now we want to know which is the most important contributor of plasma to the magnetosphere: Earth or the solar wind."

Fourteen years ago, physicists suggested that the ionized portion of Earth's atmosphere, the *ionosphere*, might feed charged particles into the magnetosphere. Electric fields created above the auroral ovals by incoming electrons could accelerate ions up magnetic field lines. When an electron falls through a potential difference of one volt, it gains an amount of kinetic energy referred to as one electron volt (eV). Electrons with energies of 1,000 eV collide with gas atoms to make up the brightest part of the auroral glow. Calculations showed that the electric field generated by these particles might give charged gas atoms just 1 eV of energy — enough to set a hydrogen ion moving at about 10 kilometers per second! Physicists called this outward flow of ionospheric gas the "polar wind."

The Dynamics Explorers detected an upward flow of hydrogen and helium ions at the predicted velocity. "Discovering the polar wind after more than 10 years of work is tremendously satisfying," says Chappell, who developed the instrument that detected it. "No one had ever seen it before because the instruments weren't set up to measure it effectively," he notes. "It's a very subtle phenomenon."

In addition to this "classic" polar wind, Chappell's instruments found nitrogen ions at altitudes as high as three Earth radii, where they had not been expected. The nitrogen ions found at high altitudes are far more energetic than those seen in the ionosphere, which have typical energies of 0.1 eV. The satellites found nitrogen ions with energies 10 to 100 times greater streaming up from Earth. This accelerated component of the polar wind, with velocities up to 50 kilometers per second, is restricted to regions directly above the polar caps, while the low-energy polar wind flows from a much larger area. The low-energy particles in the plasmasphere may once have been part of our planet's upper atmosphere.

"We're now beginning to appreciate the role played by the Earth's upper atmosphere as a supplier of charged particles to the magnetosphere," says Neal. "This is significant to our understanding of the Sun-Earth *system*." Some intriguing questions remain: What accelerates the high-energy polar wind? How does the polar wind figure in our planet's complex responses to the Sun?

Launched in August, 1981, the Dynamics Explorers returned some 90,000 images in their first year of operation. Dynamics Explorer 2 was doomed by its low-altitude orbit; it re-entered the atmosphere this February. Its high-altitude twin, however, should continue to function for another year, giving scientists the opportunity to continue their studies of the complex but unseen mediator of Earth's environment — the magnetosphere.

Comet SWIFT ~ TUTTLE & the PERSEIDS.

by
Mr. Joseph Rao.

It is mid-summer 1862 and the War of the Rebellion is well into its second year. Across the green fields and woods of northern Virginia and Maryland, two armies — one in blue, the other grey — are engaged in maneuvers that will bring them into fierce conflict at the bloody and pivotal battle of Antietam Creek in September. President Abraham Lincoln is drafting a proclamation — to abolish slavery — that he will announce a week after the Antietam slaughter.

Among soldiers and civilians alike, Victor Hugo's *Les Miserables* is the bestseller of the day. George Eliot's *Silas Marner* and Anthony Trollope's *Framley Parsonage* are also popular, perhaps because they echo the more serene tempos of peacetime. In the world of science, the controversies stirred up by Charles Darwin's *Origin of Species*, published only three years ago, are still raging — and will continue to do so for many decades to come.

1862 is a relatively quiet year in astronomy. Celestial photography is yet in its infancy, and visual work is still the rule in observatories. Every clear night astronomers can be found at their telescopes, sketching as many objects as possible, trying to learn about the mysterious patches of light strewn across the sky.

One such observer is Lewis Swift, an American astronomer who has discovered 13 comets and observed nearly 1,200 nebulae. He is a dedicated skywatcher: the fact that he badly fractured his left hip at age 13 and now walks with a limp doesn't stop him from pursuing his interests. "One cannot discover comets lying in bed," Swift often says. Although he puts in a long day at his hardware store in Rochester, New York, Swift observes on even the coldest of winter nights.

Roused out of a sound sleep by his alarm clock, he walks a half mile to Duffy's, a cider mill on White Street. Swift keeps his telescope tube and mounting on the flat roof of the mill, but getting to them isn't easy. He climbs three ladders and walks 100 feet across a sloping roof — while carrying his telescope lenses in a market basket. Quite a trip for a middle-aged man who hobbles around with a bad leg!

Since 1860, Swift has used a 4¼-inch refractor built by famed telescope-maker Henry Fitz. With this telescope, he is about to make his greatest comet find. On the evening of July 15, 1862, Swift scans the northern skies amidst the faint stars of Camelopardalis. That night, he comes across a relatively bright telescopic comet, already brighter than eighth magnitude. Now Swift knows that in most cases a comet is much dimmer than this when first sighted, so he is cautious about putting in an immediate claim. In fact, he can't believe that this could be a new comet, and writes it off as the recently discovered Comet Schmidt.

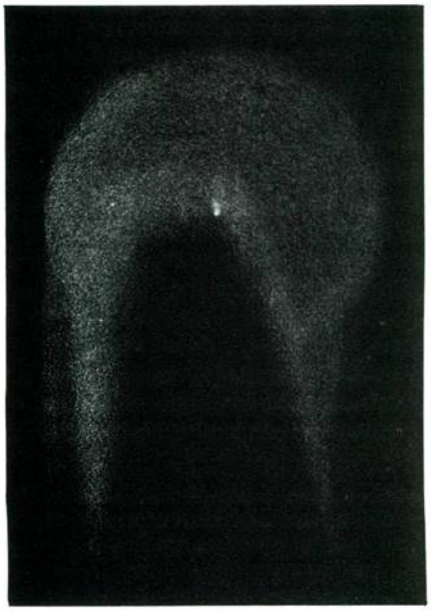
Three nights pass. No one else seems to notice the celestial visitor. But at the Harvard College Observatory in Cambridge, Massachusetts, astronomer Horace P. Tuttle spots the fuzzy patch while scanning the skies. Tuttle is also an active comet observer: in 1858 he discovered three comets and a year ago found one more. Now, on July 18, 1862, Tuttle is confident that he has sighted a fifth comet to bear his name. But on this same day, Lewis Swift, realizing that the comet is indeed a new specimen, reveals his observation of July 15th. According to protocol, the two men share the discovery, and the object is dubbed Comet Swift-Tuttle, 1862 III.

The new comet quickly brightens and grows larger. Remaining high in the northern sky through the rest of July and into August, Swift-Tuttle is a splendid sight for the naked eye because it is passing within 40 million miles of earth, and is dramatically responding to the Sun's heat. The long summer days pass, and finally on August 23, 1862, the comet is at perihelion. Luminous jets of nebulosity blossom outward from a bright, highly condensed nucleus. Some observers report seeing a short anti-tail, indicating an unusually dusty composition.

The comet's tail now stretches some 20 million miles. At its full glory the last week of August, Swift-Tuttle shines at second magnitude and displays a tail 25° long. French astronomer Camille Flammarion would rank Swift-Tuttle among the ten "really fine and striking comets" of the 19th century. Others would simply refer to it as "The Great Comet of 1862."

But as the weeks move into September, the great comet becomes a ghost of its former self, rapidly fading as it recedes from the Earth and the Sun.

This sketch by the German astronomer J.F. Julius Schmidt shows Comet Swift-Tuttle's nuclear region on August 20, 1862. All sketches in this article are by Schmidt and were originally published by the Athens Observatory in 1863. They are reproduced courtesy of Bertram Donn — from NASA's *Atlas of Cometary Forms*.



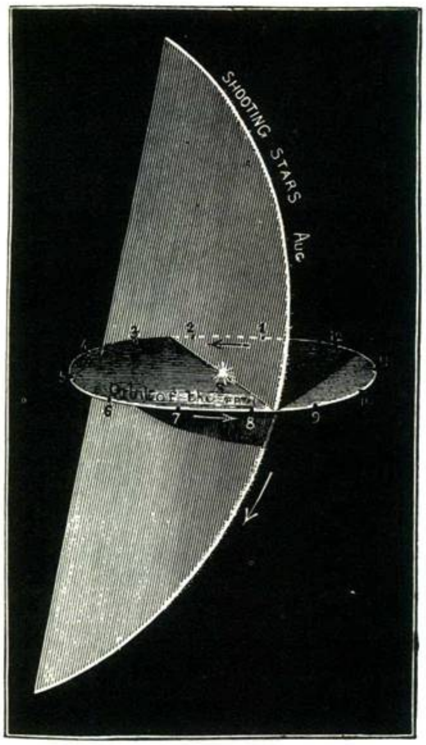
It drops far south in declination, precluding any further observations from the United States. Indeed, the last known sighting comes on October 27th from the Cape Observatory in South Africa.

* * *

And so goes the story of the discovery and most recent apparition of Comet Swift-Tuttle. From this bright visitor we learned quite a bit about comets in general and their relationship to meteor showers. Among the interesting points raised by the comet's appearance were a couple of surprises. The first is that Swift-Tuttle's orbital period does not run in the hundreds or thousands of years, as so many large and bright comets tend to. Swift-Tuttle goes out to a distance of nearly 48 astronomical units at aphelion — its farthest point from the Sun — and takes just under 120 years to make one trip around it.

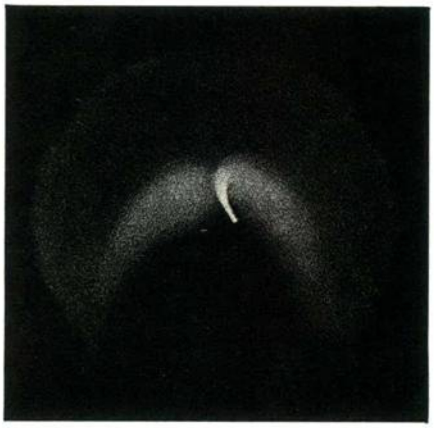
A second surprise came from the Italian astronomer Giovanni Schiaparelli. In 1867 he announced that the orbit of Comet Swift-Tuttle appeared to be nearly coincident with the orbit of the Perseid meteors. Those swift streaks of light appear to dart across our northern skies from their namesake constellation from late July through most of August.

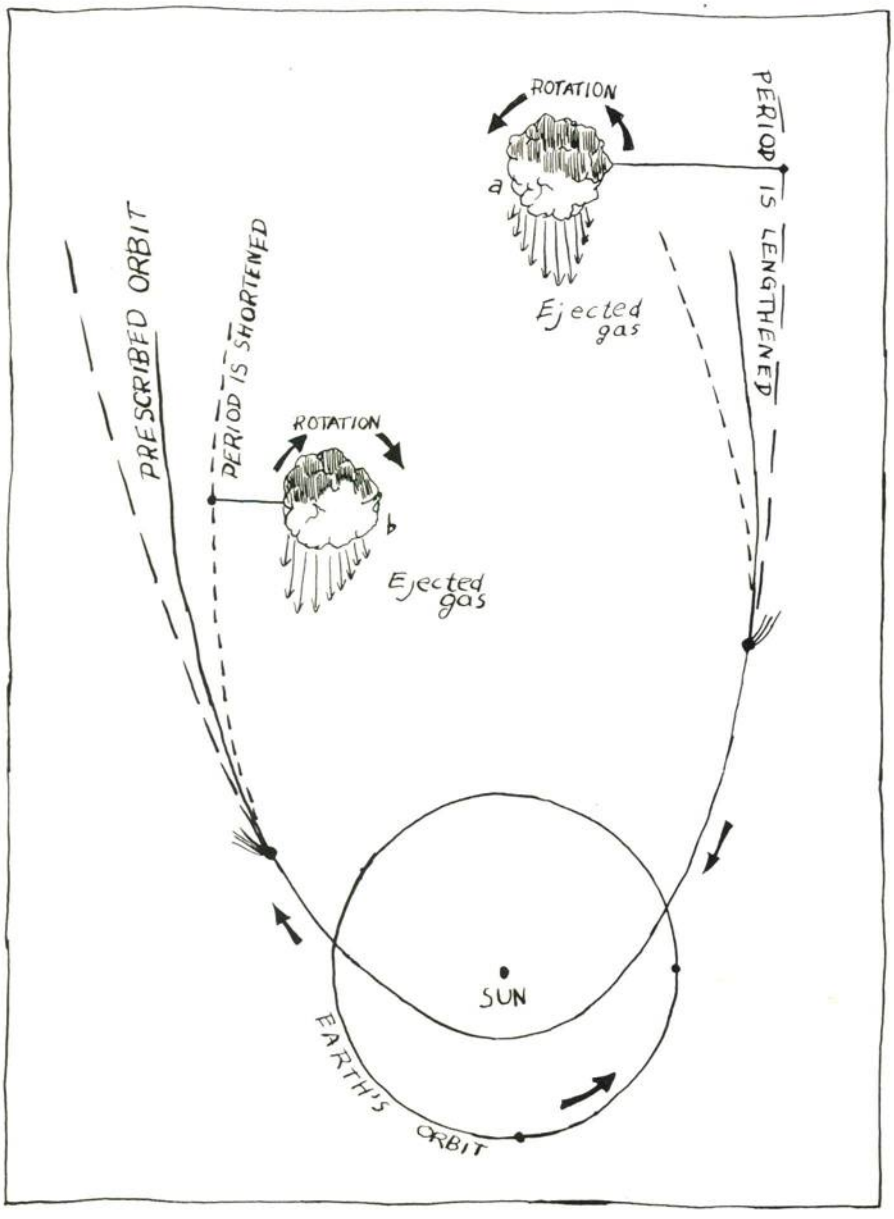
Once this similarity was known, Schiaparelli realized that Comet Swift-Tuttle and the Perseid meteors were related in some way; the August "shooting stars" were, in all likelihood, fragments of the comet that had somehow become separated from it.



The orbit of the Perseid meteors relative to that of Earth.

On August 26, 1862, Swift-Tuttle's nucleus appeared as a tiny curved spike with bright fan-shaped nebulosity and a faint outer halo. The comet was then 37 million miles from Earth.





When any comet swings in close to the Sun, radiation ionizes and evaporates its ice and gas, causing a "thrust" on the comet. If a comet's nucleus is rotating in the same direction as its motion around the Sun (a), the delayed jet reaction pushes the comet forward in its orbit. The nucleus drifts away from the Sun, the orbital period increases, and the next time around the comet shows up later than expected. If the comet's nucleus rotates in the direction opposite to its motion around the Sun (b), the comet experiences a "drag" force and moves in toward the Sun. The orbital period decreases, and the comet's return is earlier than expected.

These cometary fragments are called *meteoroids* while they exist in and move through space. But a *meteor* is not a particle of matter itself. It is merely the short-lived streak of light produced by the meteoroid as it is heated to incandescence by its plunge through the Earth's atmosphere. The kinetic energy released per gram of the meteoroid's weight far exceeds the energy efficiency of the most powerful man-made explosives. Thus, a pebble-sized object can create a substantial meteor trail. If Schiaparelli was correct, Swift-Tuttle is the progenitor of the Perseid meteor shower — the first direct correlation to be found between a comet and a meteor shower. Soon afterward Schiaparelli suggested that another annual display, the November Leonids, was caused by Earth's interception of the debris of a comet discovered in December 1865.

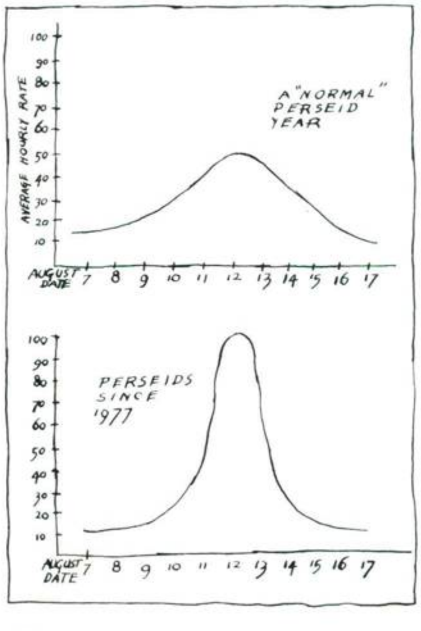
August 31, 1862: the comet appeared to be more spherical than the past few days.

Today, while not all meteor showers have been associated with specific comets, astronomers think that all showers probably have a cometary origin. Over 500 cometary meteor swarms that produce (or have produced) meteor showers are currently known.

With a period of 120 years, you'd think that Comet Swift-Tuttle is due back at any time. But unlike Halley's Comet, which has been painstakingly observed by the Chinese on 28 separate occasions at 74 to 79-year intervals back to 240 B.C., Swift-Tuttle lacks a similar past history. Apparently it has been recorded just once — in its discovery year of 1862. And with no other definitive pre-1862 observations, the comet's 120-year period can only be called an approximation at best, with an uncertainty of at least several years. In calculating the orbit of any newly discovered comet, two factors usually come into play: planetary perturbations and non-gravitational forces. Planetary perturbations are the gravitational effects of the planets on a comet; non-gravitational forces are more complex. If a cometary nucleus rotates — and we have yet to find a celestial object that doesn't to some degree — then its rotation, coupled with the way it throws off material under the influence of the solar wind, can lead to motion that mimics that of a spacecraft with booster rockets.

A decade ago, Brian G. Marsden, head of the Harvard-Smithsonian Center for Astrophysics, investigated possible sightings of the comet before 1862. But after checking through all available historical records, he found no promising candidates. This result is baffling since this comet is apparently the type of object that can be glimpsed with the unaided eye during relatively close encounters with the Earth. In fact, should it come to perihelion around the 29th of July this year, a near collision with Earth would be inevitable some two weeks later. Indeed, the orbit of the comet at that point in space literally grazes that of Earth's; the distance between the two is only 0.00004 AU (less than 4,000 miles). Any perihelion occurring from late June to early September might make Swift-Tuttle a naked-eye object. "One would expect this to happen during one revolution out of every five or six," notes Marsden.

The normal rate of Perseid meteor activity (top) contrasts with the unusually high numbers of Perseids recorded since 1977. Coincidence or foreshadowing?

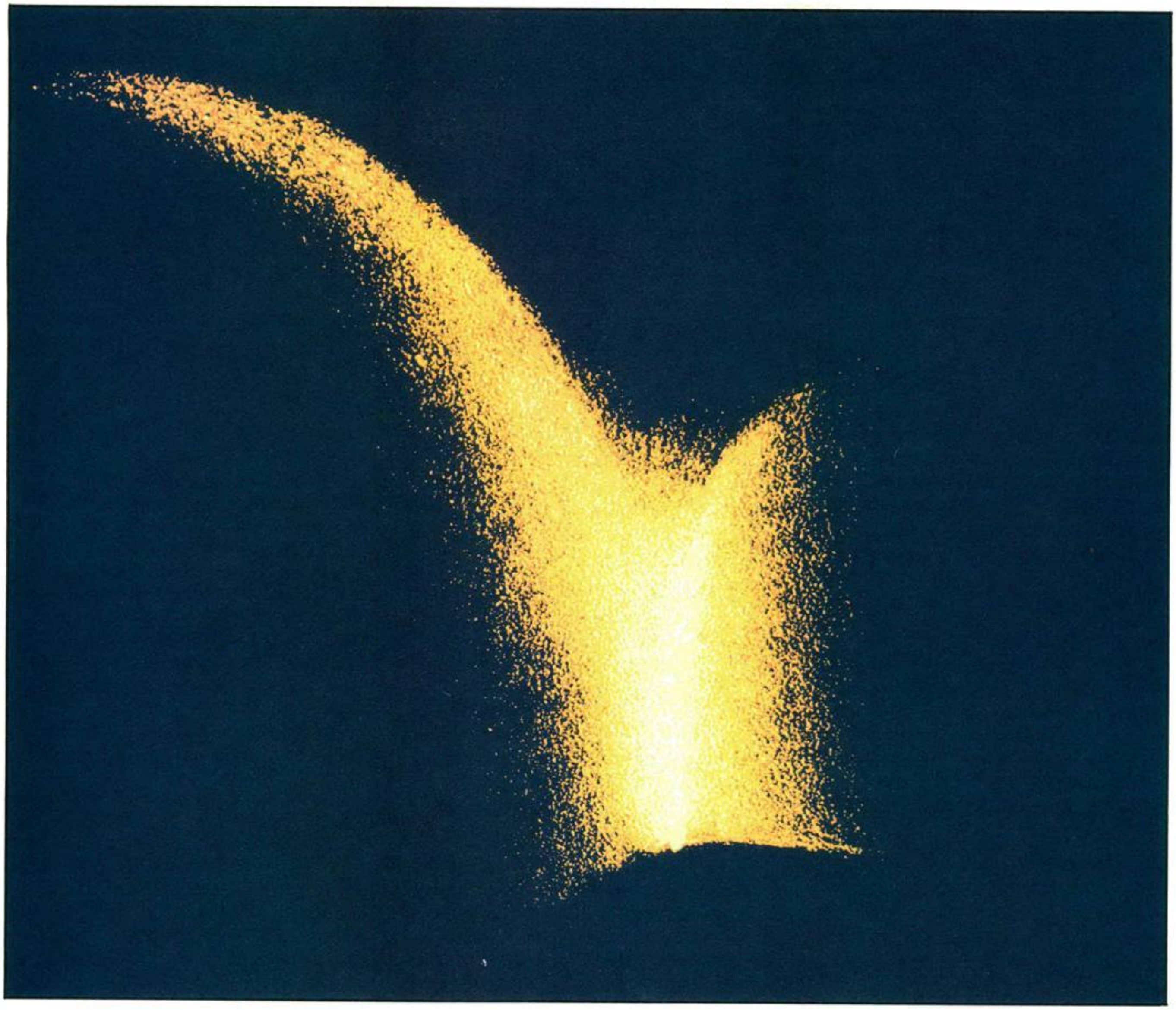


On the other hand, if the comet were to return in January or February 1984, it could easily be missed because it would be on the far side of the Sun as seen from Earth, and hence very faint.

Possibly, Comet Swift-Tuttle was anomalously bright in 1862. Perhaps it circled the Sun for untold millennia as a small, faint comet, always beyond the reach of the unaided eye. Then, suddenly on its way in toward the Sun in 1862, it may have suffered some major outburst or flare-up of activity from within its nucleus, allowing us to detect its presence. This would be unusual, though not at all impossible. In recent years, we've seen a few comets go through such flare-ups: Comet Schwassmann-Wachmann 1 periodically undergoes surges in brightness as it moves around the Sun in a near-circular orbit close to Jupiter. Comet D'Arrest appears to brighten suddenly just a few weeks after perihelion, when a "normal" comet should fade.

In fact, what happened to Swift-Tuttle might be analogous to the antics of Comet Tuttle-Giacobini-Kresak (1973 VI) in 1973. Tuttle originally discovered it on May 2, 1858, but it was not seen again until M. Giacobini at Nice Observatory in France picked it up on June 1, 1907. Thus it went unseen during nine revolutions around the Sun. Astronomers missed eight more returns before L. Kresak at the Skalnate Pleso Observatory in Czechoslovakia recovered it on April 24, 1951.

Like Swift-Tuttle, Comet 1973 VI has a long-standing uncertainty in



This enlarged view of Swift-Tuttle's nucleus — made on August 29, 1862 — clearly shows the separation of the two primary "fans" of gaseous material.

its orbital period — hence its ragged observational history. Both comets can be poorly placed on some returns. And neither comet comes exceptionally close to the Sun at perihelion.

Yet 1973 VI surprised observers around the globe by becoming far brighter than anyone anticipated. Comet 1973 VI was not expected to be any better than magnitude 13 at perihelion on May 29. But between May 20 and May 27, the comet jumped from magnitude 14 to 4, increasing its brilliance by 10,000 times. It gradually faded to magnitude 15 on July 4, but then brightened again to magnitude 6 only two days later. After another week, it completely faded out of sight for amateur telescopes.

This shows how a comet can go around the Sun on numerous occasions as a staid and respectable member of the solar community, and then abruptly and unpredictably show violent changes in brightness. For a short while, 1973 VI could even be glimpsed with the unaided eye, although normally when at perihelion, it would be about as easy to spot as Pluto.

Could Comet Swift-Tuttle have undergone a similar outburst in 1862? Had it gone unseen at other returns because it was just too faint to see without a telescope even at its most favorable viewing interval? Will the impending return of Swift-Tuttle be as spectacular as 1862, or will it be nothing more than a paltry blur of light, visible only in the largest telescopes?

When Marsden searched for early sightings of Swift-Tuttle, he found a possible candidate in a third-magnitude comet observed on eight consecutive nights in July 1737. The comet was recorded by the Jesuit missionary Kegler in Peking; his records show that the brightness and

On August 17, 1862, Comet Swift-Tuttle approached within 55 million miles of Earth and 90 million miles of the Sun. In one of Schmidt's remarkable sketches, he recorded a dark patch in the coma's head and an inward gas jet near the nucleus.

position of this comet are remarkably similar to Swift-Tuttle's. The only problem is that it appeared on the scene too early — at least if we use the currently accepted 120-year period.

But Comet Swift-Tuttle and Comet Kegler could be one and the same if we assume that maverick motions due to non-gravitational forces are at work. In this particular case, such forces could accelerate the comet, expanding its orbit and delaying its arrival at perihelion.

If this is true, then previous perihelion dates would have occurred near March 1610, December 1479, and September 1348. There are no records of any comets for the first two dates, but remember that visibility of Swift-Tuttle is at its worst around January and February, so a March or December sighting would be unlikely. Conversely, from late June to early September Swift-Tuttle would possibly brighten to naked-eye visibility. And indeed, there is a Japanese account of a comet in September 1348. Coincidence?

After taking all this into account, Marsden suggested a new course of action: projected calculations indicate that if Swift-Tuttle does not reappear before late 1983, the search should be resumed in 1992 on the possibility that Kegler was indeed Swift-Tuttle. The possible date of perihelion for that year is November 25. If the comet does come back then, it will be another step forward in the better understanding of the theory of non-gravitational forces, as well as comets in general.

Perhaps Swift-Tuttle has been here already. Over the past few years amateur and professional astronomers have looked carefully for Swift-Tuttle using a search ephemeris calculated by Marsden. He determined that several "search windows" — probable areas where the comet could be found — would open up in 1980, 1981, and 1982 and would offer the best chances for recovering the comet. But success has yet to come, leading Marsden to remark, "It would be a shame if too much concentration on a window prevented us from picking up a comet through an open door!"

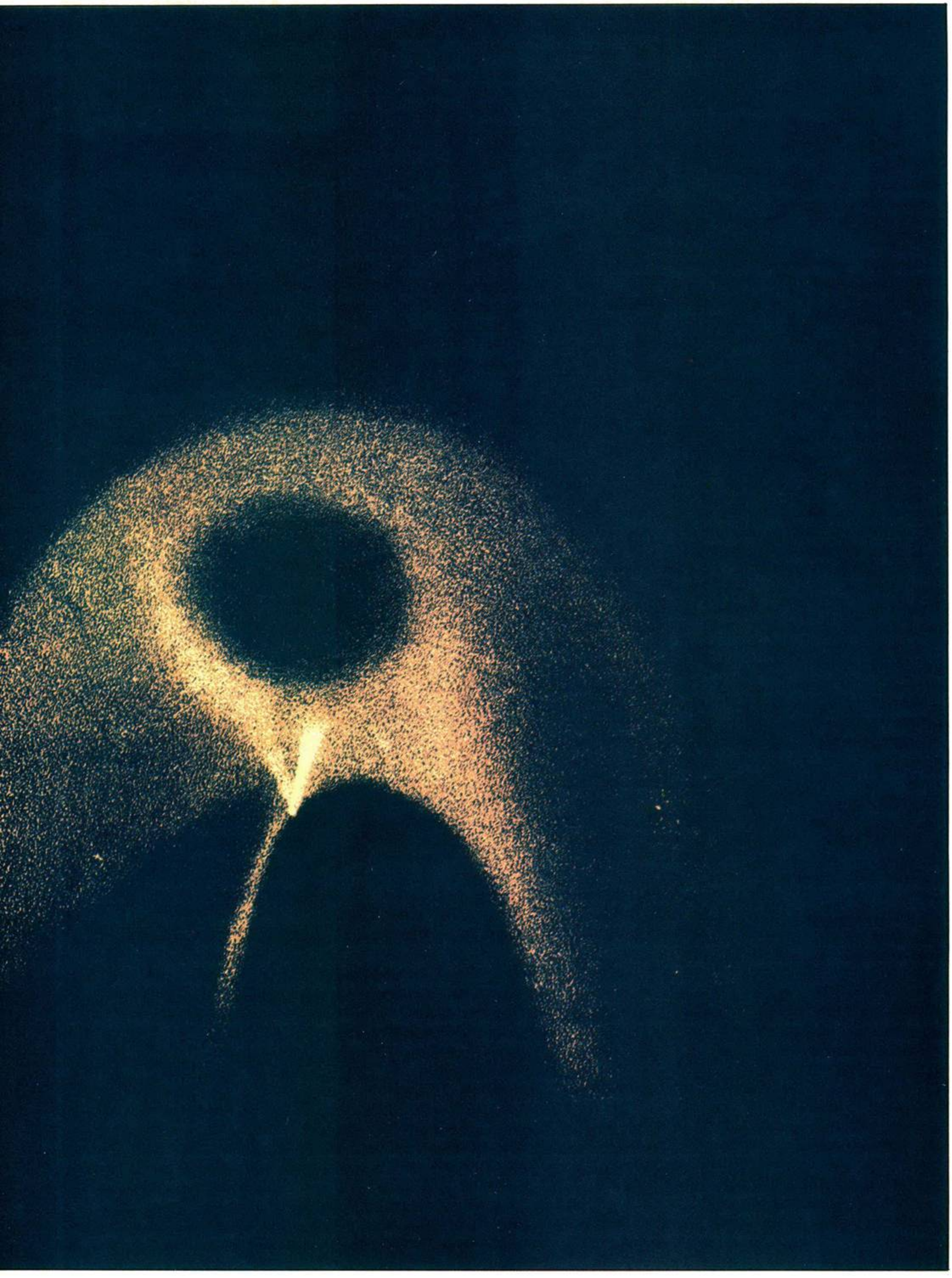
Yet some circumstantial evidence supports predictions that Swift-Tuttle is somewhere near the inner part of the solar system. Since the mid 1970s, the Perseid meteor shower has increased in activity, showing a high number of bright fireballs and bolides. Until a few years ago, astronomers thought that debris from Swift-Tuttle is distributed more or less uniformly all along its orbit. If this were true, the Earth would encounter the same number of Perseids from year to year — enough to produce about 30 to 50 naked-eye meteors per hour. But during the past few years, the rates have been closer to 100 to 200 per hour.

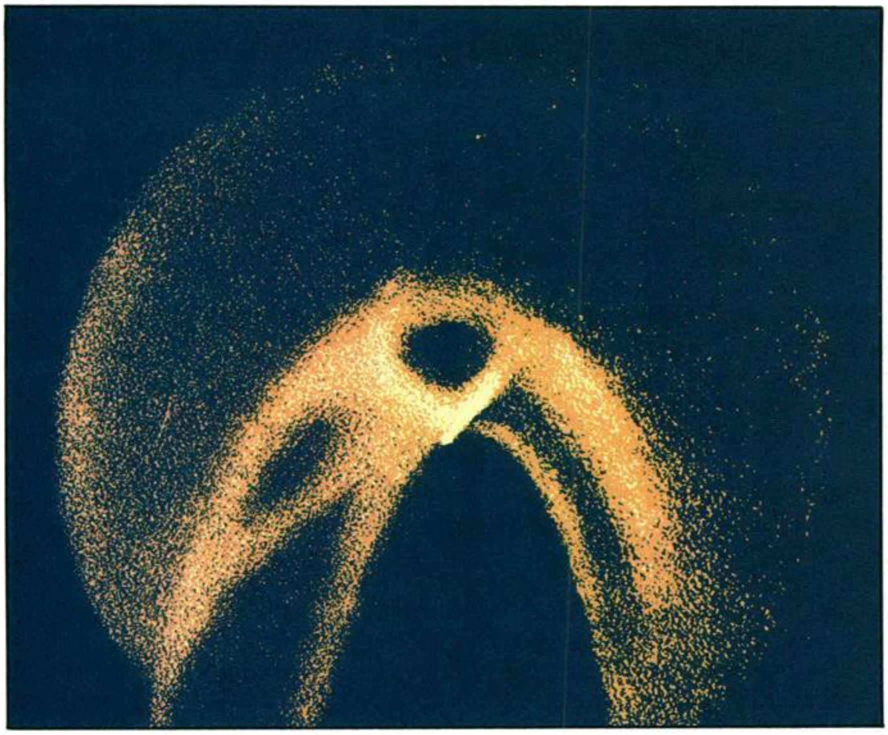
Kenneth L. Franklin of New York's Hayden Planetarium believes that the high rates and preponderance of fireballs may be traceable to "comet fragments which did not have the energy to go as far away as the main body. So they have been returning early, having made a shorter trip."

Thus, as old as the shower is (about 100,000 years), there might still be several concentrations of meteoric debris accompanying Comet Swift-Tuttle in its orbit. While the first Perseid shower appears to have been recorded by the Chinese in the year 36 B.C., the display has been abundant since 830 A.D. Spectacular showers, in which Perseids apparently fell every few seconds, were recorded in early centuries. The most notable showers occurred between 830 and 841 A.D., between 924 and 933, and then in isolated displays in 989, 1007, 1451, and 1862.

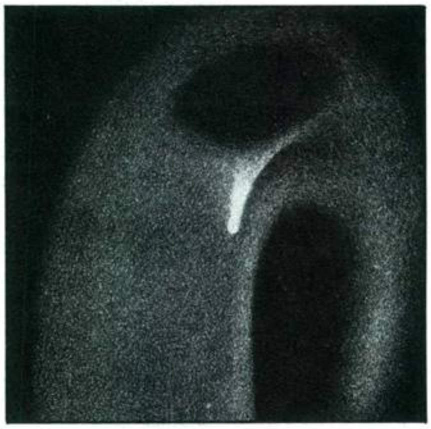
But still a Perseid/Swift-Tuttle connection is not all that easy to make. There is still a wrinkle to iron out. In 1921 Estonian astronomer Ernst Opik showed that the total mass of the Perseid stream was equal to one billion tons. In 1933 he refined this estimate to 10 billion tons. But by the early 1950s, it became clearer to Opik and his colleagues that naked-eye meteors were not strong homogeneous structures, but loosely bound aggregates — tiny dustballs that break into still smaller fragments under the slightest bit of air resistance.

Consequently, the average meteor shower particle was far more massive than expected; Opik upped his estimation of the total mass of the Perseid swarm to 200 billion tons. This figure is nearly equal to the upper limit of cometary masses estimated by Fred Whipple in his icy-nucleus model





This sketch — made on the 27th of August, 1862 — shows intricate detailed structure within the comet's nucleus.



On August 30, 1862, the comet presented an unusual curved structure with dark patches. At this point Swift-Tuttle made its closest approach to Earth, about 31.5 million miles.

of comets proposed in 1950.

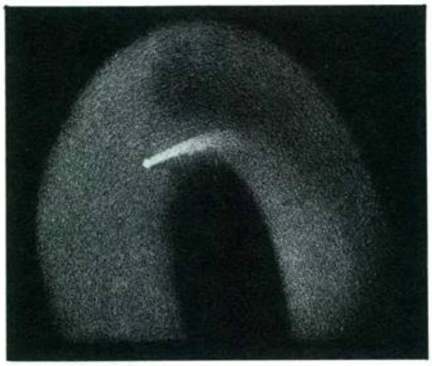
But the total mass of Comet Swift-Tuttle itself could not be much greater than this. How then, can a comet that has lost so much of its mass still remain intact? Two associates of Opik, Peeter Muursepp and Raimund Preem of the Tartu Observatory, Estonian S.S.R., suggest that Swift-Tuttle might actually be one of several comets traveling in approximately the same orbit, all giving up material to the Perseid swarm.

A meteoroid swarm is sometimes referred to as a "flying gravel bank," though it is not a very compact one. The Perseid meteoroids, for example, are anywhere from 60 to 100 miles apart at the densest part of the swarm. Earth enters the outer fringes of the gravel bank around July 25, but does not leave it behind until we see the last stragglers around August 18. All told, the Perseid stream is immense — perhaps as large as 50 million miles in diameter.

Earth encounters the "core" of the Perseid swarm, where meteoroid concentration is at its densest, around August 12. This is when the Perseids put on their best show, as the meteors appear to diverge from a patch of sky near the Double Cluster in Perseus — actually an illusion of perspective, since that is the direction toward which the Earth's orbital motion carries us at this time of the year. At the same time, the meteoroids are traveling on parallel paths nearly perpendicular to Earth's orbit. The combined speeds of Earth and the meteoroids cause the Perseids to rush into our atmosphere at average speeds of 37 miles per second.

Until Swift-Tuttle finally reappears, the Perseid meteor shower should certainly be scrutinized for a possible occurrence of lots of bright meteors. It's obvious that Swift-Tuttle released a large amount of new material into the inner solar system in 1862, but exactly how this new cloud of particles has behaved is anybody's guess. Some of the greatest meteor showers of the past — the Leonids of 1966, the Draconids of 1946, and the Andromedids of 1885 — produced meteors by the thousands per hour when we passed through the wake of debris shed by comets near perihelion. Will we see a similar magnificent display materialize in the coming years with the Perseids? The display that came in the year of Swift-Tuttle's perihelion was a good one, though nothing compared to the three best showers.

Have the Perseid displays of the past several years been just a tease? Will the display return to normal intensity in the years ahead? Or will we be treated to a truly spectacular shower? There can be no greater incentive for meteor watchers to be out in force this month. The Moon will be dark and the meteors bright.



On September 2, 1862, Schmidt sketched a broad loop of nebulosity arcing around a bright elongated nucleus.

Joe Rao is a meteorologist at Compu-Weather in Flushing, New York. He is also an active observer and is associated with New York City-based astronomy clubs.

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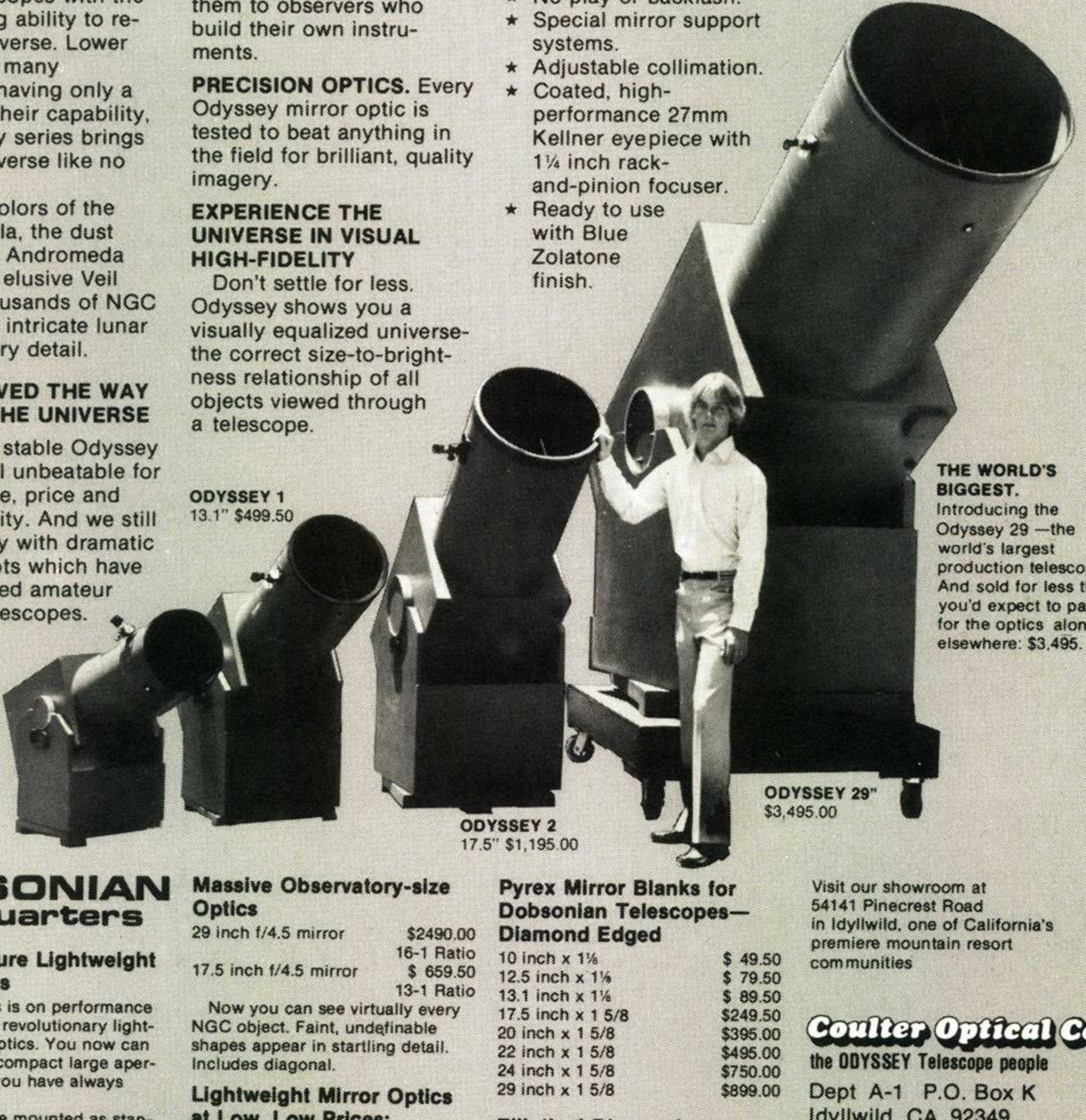

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Sudden Comet

I didn't know of the comet's existence until Fred Schaaf telephoned me on Monday, the 9th of May. He talked for two hours over a distance of half a thousand miles — a measure of his enthusiasm.

Yet I experienced a momentary guilty reluctance to hear about a sudden comet — I was in the middle of so many other projects. But then the figures he read to me sank in: declination 73°, the next day 61°, the next day 21° — how could it stride so fast over the sky? Inclination 73°, perihelion distance 0.9913 AU — the comet was arching through the polar constellations, sliding down on us like a missile lobbed across the Sun, and very accurately! Minimum distance from the Earth expected to be only three million miles — no known comet has come nearer except one, Lexell's, and that was in 1770.

What was the new comet's name? The first of a new kind: IRAS-Araki-Alcock, because the first of its three discoverers was not a human being but a scientific satellite.

Everything about this comet was a long shot:

First, that it should come from the recesses of space to hit the orbit of our planet so nearly exactly. Something like firing a needle from Canada to hit a thread of cotton in Antarctica.

Then, that its perihelion should be at this place — actually, a little inside the Earth's orbit and below the ecliptic.

Then, that it should arrive at this point on Earth's orbit at the moment in the year when the Earth was there — that it should come to the mid-May part of our orbit in mid-May. Actually, it was just a day late. If its errand was to ambush this planet, it missed and fell just behind.

Then, that it should come at New Moon.

And finally, that it should come during a week of perfect weather. Well, almost. Again, it would have done better to get here a day earlier.

And as it came arching down from the north, it descended closely past a series of skymarks spaced to make its position easy to describe on each successive night. Kochab in the bowl of the Little Dipper, then next night Dubhe in the bowl of the Big Dipper, then next night all the way to the Praesepe cluster in Cancer, then to the head of Hydra and the cluster M-48.

That Monday night, I set my large binoculars on Kochab from a lawn among trees on a campus six miles from a city. Nowadays, that's inside the yellow dome of light pollution. Cupping my hands to fend off stray light, I slowly realized that there was an effect which was not stray light: it kept to its position under Kochab. Its existence was subtle; it was not an object but a presence. The people with me could not see it — or I couldn't persuade them that they could.

Looked at directly it faded, but when the eyes wandered up and down at the other side of the field — even better, when I moved or shook the binoculars — the presence stole out of hiding. And it had structure, all the more convincing for being the wrong structure: slightly fan-shaped, but the

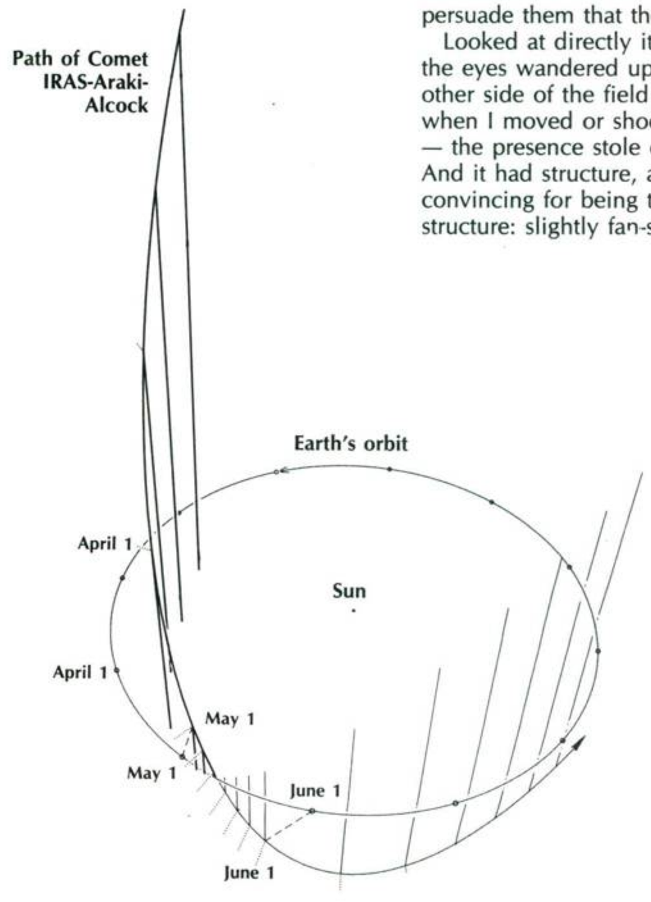

diagram by Guy Ottewell

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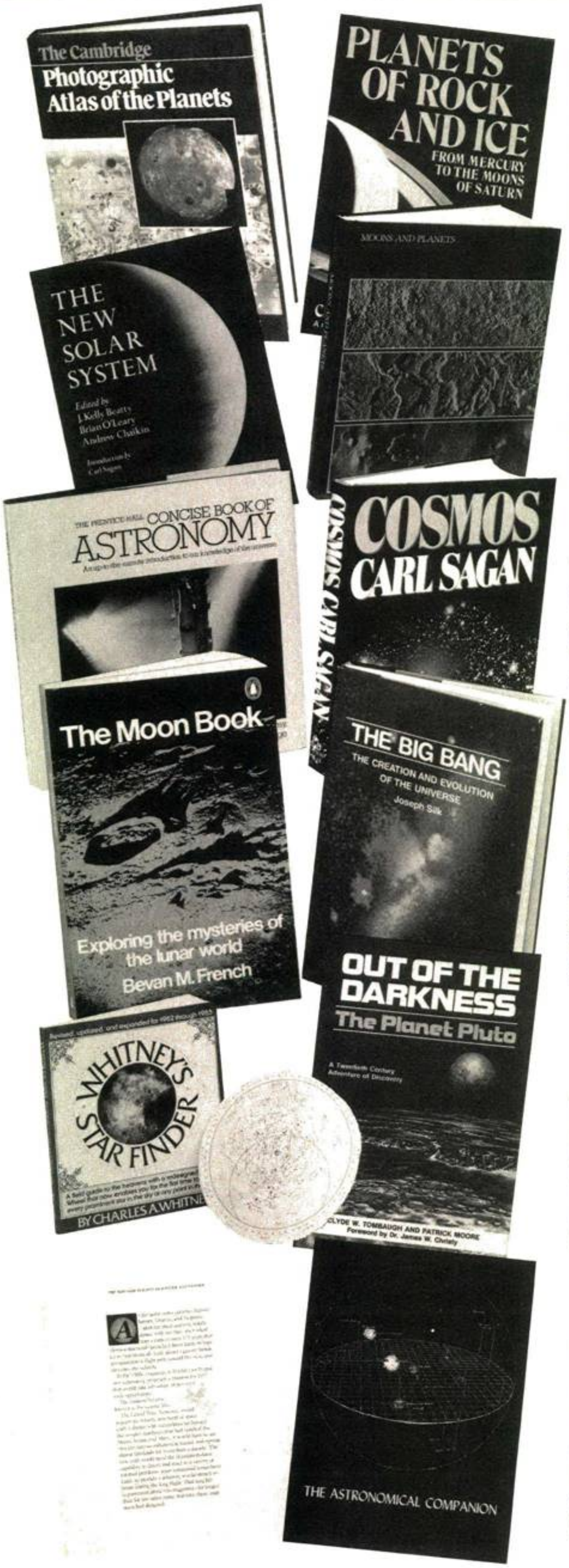
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fan pointed in an unexpected direction, almost toward the Sun instead of away.

Tuesday night, out along a country lane, a patch of rough open ground, the entrance to a lumberyard. Immediately IRAS was obvious to the naked eye. More than a degree across, already halfway from Dubhe to the Great Bear's forepaws.

Earlier in the evening I had been preoccupied with something on a different plane of importance, an Amnesty International meeting. Then I had tried again to find the comet for some people from a hopeless location. So it was eleven o'clock before I got out here. The comet seemed all the larger for being lower in the sky. In front instead of above, it confronted me with its nearness. Off the end of the Earth — a little gauze wafting in front of a few of the stars — only 15 times as far away as the Moon!

Daniel Marcus/Bill Smith

Imagine that this thing has eyes. It lives in space out toward the Pleiades for a hundred million years of time that cannot seem like time because nothing changes. At last time becomes time, the brightest of the spots on the celestial sphere rushes toward it but swerves aside, and then more exactly ahead there looms up a blue marbled planet. . . .

In binoculars it was smaller, but its shape was more definite. Almost as an afterthought, I looked at it with the telescope. I assumed that higher powers would make it fade. But there it was, smaller and more definite again, five-eighths of a degree across, stretched among a network of stars.

There again was the fan-shape, perversely pointing ahead in the direction of motion. But perhaps I was wrong about it: the impression of a concentration at the other end, the fan's handle, might be due to (or at least enhanced by) that star that was superimposed. For there was a short line of three stars; the middle one was brightest, and the northwestern happened to coincide with the comet's nucleus. That is to say, the comet's head, for of course you cannot actually see the nucleus of any comet. But if that star were really part of the comet, I would see it move away from the other two stars.

And in seconds the line of three stars became a bent one. I could see the third "star" moving like the hand of a clock; in five minutes it was far to the left. It was the center of the comet's head, but it was not merely a dense inner concentration of the cloud, it was distinct from it. As far as I could tell from much staring, it was strictly stellar and point-like.

Never before has the nucleus of a comet been seen; it is something that exists only in theory — the current provisional theory of what a comet is. Big telescopes searched in vain for the nucleus of Halley's Comet when it should have been silhouetted against the Sun. But here am I looking at the nucleus of a small comet, with a three-inch telescope!

It occurred to me that if someone were to get a light-curve for it, and find it undulating like an asteroid or satellite — tumbling — that would clinch its solidity. The excitement was of course being felt in many places.

On Wednesday morning at 8 a.m., the comet was closest to Earth, and through the day the telephones were humming — "They say it's moving south so fast that it's hard for the big telescopes to track it" — "They're talking about the gravitational effect on it of the Earth. . . ."

On Wednesday night there were two comet-patches side by side in Cancer — the comet and Praesepe — and at ten o'clock, passing Delta Cancri, it visibly and perpendicularly pierced downward through the ecliptic plane. A firm layer of cloud had arrived from the west to end the magic spell of weather, so these things were visible to the mind only. Yet at midnight I found to my surprise the clouds had cleared, so I hurried out again to the country. With a struggle I gained one more glimpse of IRAS, very low, before she fell onward through the horizon.

Cleopatra: . . . Farewell, kind Charmian, Iras, long farewell. [Iras falls and dies.]
— *Antony and Cleopatra*

Guy Ottewell
Greenville, SC

See the Universe!

As dusk approaches, huge hand-crafted telescopes point upward to the stars. Talk of "possible turbulence," "deep-space viewing," and "spiral galaxies" rings throughout the cool mountain air. Crowds of curious onlookers half-suspiciously keep watch on a handful of crew members busily focusing, checking, and preparing. There's going to be a star party.

The San Francisco Sidewalk Astronomers' telescopes occupy a patch of ground near the top of Fremont Peak State Park. Far below, under rolling waves of fog, is Salinas. Luckily, up here the skies remain clear. The many who came to "See the Universe!" — as the Sidewalk Astronomers' flyer invited — will not be disappointed.

Throughout the day, carloads of astronomy buffs and their families set up their camps and telescopes. No scopes, however, are as impressive as those of the Sidewalk Astronomers: they carry the tubes in 25-foot motor homes and the bases in large trailers. The group owns the largest portable amateur telescopes in the world, some of which demand six adults for assembly.

Back in the city, smog and lights prevent the Sidewalk Astronomers from showing deep-sky objects. But they can show the planets and the Moon.

"Come and see the Moon!" they call to passers-by in front of Ghirardelli Square on nights near First Quarter Moon. Some people think they are crackpots or hucksters, and walk on by. Those who do stop are in for a treat. When they peer into the ocular, amateurs inform them that "the smallest dents are each the size of a large city," and that the Moon's rough texture is a result of "target practice" from meteorites.

During the day the Sidewalk Astronomers point their scopes at Sol. John Dobson, founder of the group, frequents Golden Gate Park, where many tourists and natives alike get their first look at the Sun. The group's energetic president, 25-year-old Gerard Pardeilhan, totes his telescopes all over, as another might tote a sketch pad or a camera. When he lived in Berkeley, he often wheeled his 5-foot-long, 10-inch diameter telescope to UC's Sproul Plaza in an abandoned shopping cart. I've seen Gerard with his telescope everywhere, from the Tilden Regional Park Autumn Festival in the East Bay to the Napa Greyhound Station, where he entertained people while waiting for a bus. He even has a favorite photo of Mayor Dianne Feinstein peering through it at the San Francisco Civic Center. "Each of those specks you see," Gerard tells viewers, referring to black dots on the Sun's yellowish disk, "are sunspots. They are caused by solar storms. Most of them are about the size of the Earth."

At age 14 Gerard looked through a

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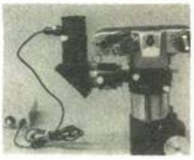

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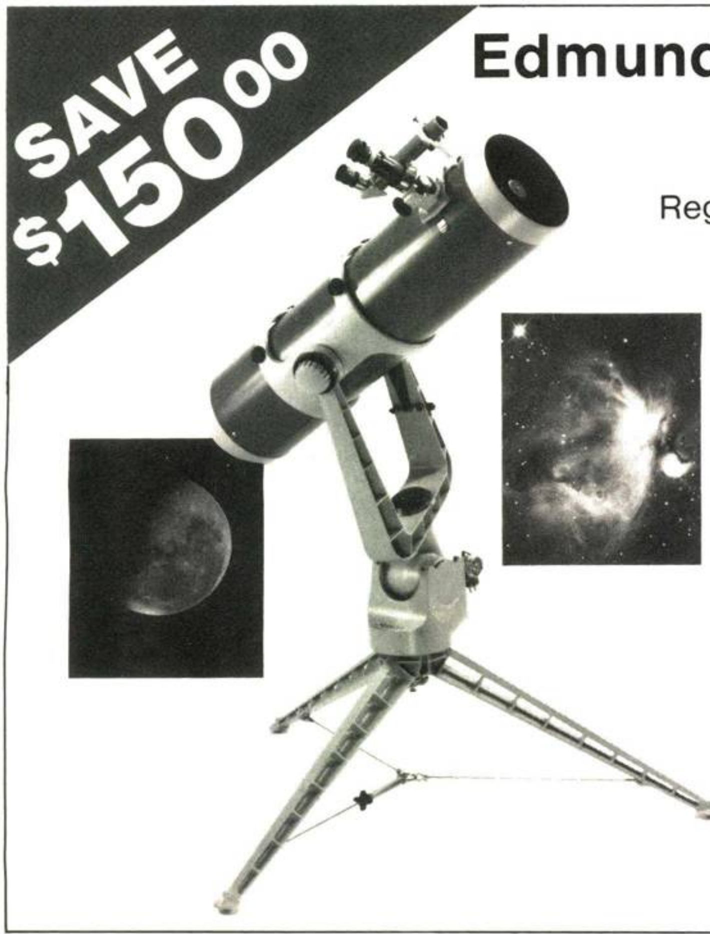

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neighbor's telescope. Already a science buff, he was enthralled. A year later he borrowed a telescope-making book and made his first instrument — a 16-inch reflector. Because of his love of working with glass, Gerard became an optician at an optical research company. He works on such projects as the prototype 10-meter mirror planned for installation in Hawaii by the University of California.

Dobson, who is 64, also learned to figure telescope mirrors from a book. Full of questions about the nature of the universe, he wanted to observe it more closely. A penniless Vedantin monk, he used the bottoms of gallon jugs to figure his first mirrors. Devising a portable mount, he wheeled his telescope around the neighborhood, showing stars to children and anyone else who cared to look. Eventually he spent so much time with astronomy that after 23 years, he was asked to leave the monastery. Undaunted, John moved to San Francisco and became a full-time amateur astronomer.

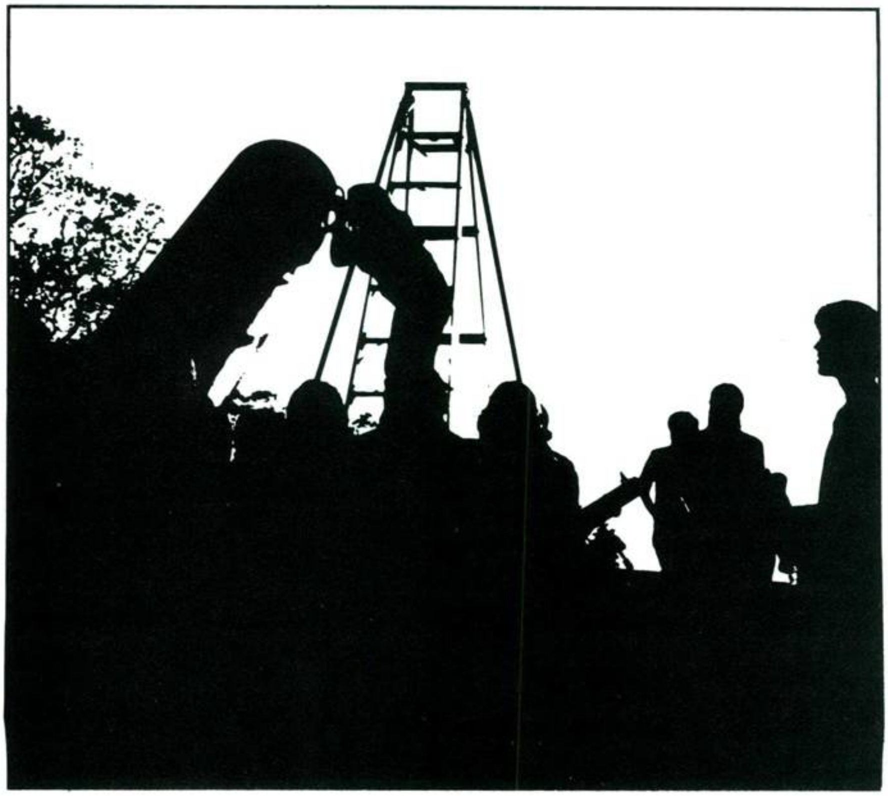
Looking through the window of the motor home on Fremont Peak, he says, "I never would have imagined this!" Most of the telescopes people brought were "Dobsonians" — the very kind John devised when he was living in the monastery. Mounted on a swivel base, with the tube set in a rocker, they look like cannons. They are inexpensive and are practically made from junk: tubes are cardboard concrete column forms; mirrors are old navy portholes. Yet the design is effective — and good enough for serious star gazing.

"If I had patented the design," says John, "I'd be a rich man now." But he is interested in spreading the word about astronomy, not making money. Someone recently calculated that, because he had to travel, John made only $1 per hour teaching his astronomy class. But money is not a major concern to Dobson, as long as the group keeps going. It does this by charging membership dues of $15 per year and by accepting donations.

As part of their park program the Sidewalk Astronomers provide a slide show, which helps the public better understand what they will view in the telescopes. With the arrival of twilight, everyone on Fremont Peak gathers for the show. Some people have folding chairs, but most sit on the rocky ground. Relaxed and charming, John changes the gravel parking lot into a space ship, taking the audience on a ride through the universe.

He mentions ideas about the origin of the universe; he shows a computer simulation of the Whirlpool Galaxy and close-ups of planets. He shows a slide of galaxy NGC-4565, which he calls "Bernice's Hairclip" because it lies in Coma Berenices. Such quips make the audience laugh, comfortable with the folksy way he talks about space.

After the show the crowd leaves *en masse* to look through the huge telescopes they've been eyeing all day. Beside the larger scopes are stepladders with crew members perched on them, busily looking through the eyepieces and making last-minute adjustments. All around the campground, others who have brought their own scopes find objects to view and ready themselves for the people they hope will come by. Music from *Cosmos* softly fills the air, coming from a van displaying the California license plate "GAZER."



It is too early to look at deep-sky objects: all of the telescopes point toward planets. Immediately a line forms behind the 24-inch scope called "Delphinium." Another forms in back of the nine-foot-tall, 18-inch aperture "Little One." I wander over to one of the smaller scopes for a look at Saturn. The rings are strikingly clear.

After three or four people look through a telescope, a crew member must realign it because the planet drifts out of view — a reminder that we, too, are on a revolving planet.

Later, as the sky darkens enough to permit finding fainter objects, telescopes move, and there is newfound enthusiasm for objects that are stranger yet. One of the scopes features M-13, the Great Hercules Cluster. Group members inform the crowd that this fuzzy thing is 30,000 light-years away. They further state that this means we see it as it was 30,000 years ago. To the crowd this is a magical fact, and they stare through the eyepiece like they've just seen a ghost. There are squeals of delight, and a woman in one group who just happened to be camping at Fremont Peak exclaims, "Aren't you glad we came? This is great!"

I once asked Gerard why he spent so much time showing people the stars. He answered: "When people look through telescopes they discover that something they thought was mysterious and always would be mysterious is no longer mysterious." He paused, remembering a boy of fourteen who looked for the first time through a neighbor's telescope. "I like to bring my telescope to the public because I want to spread the excitement I first had. I want to experience that excitement over and over. It makes me feel . . . alive."

Throughout the night, telescopes swing to more and more objects. At least for a night, astronomy is out from the realm of scientists taking spectral plates with exotic CCD imagers. It is brought to secretaries and lawyers and postmen and fourth graders — all of whom, feel the members of the Sidewalk Astronomers, deserve to know a little more about the universe in which they live.

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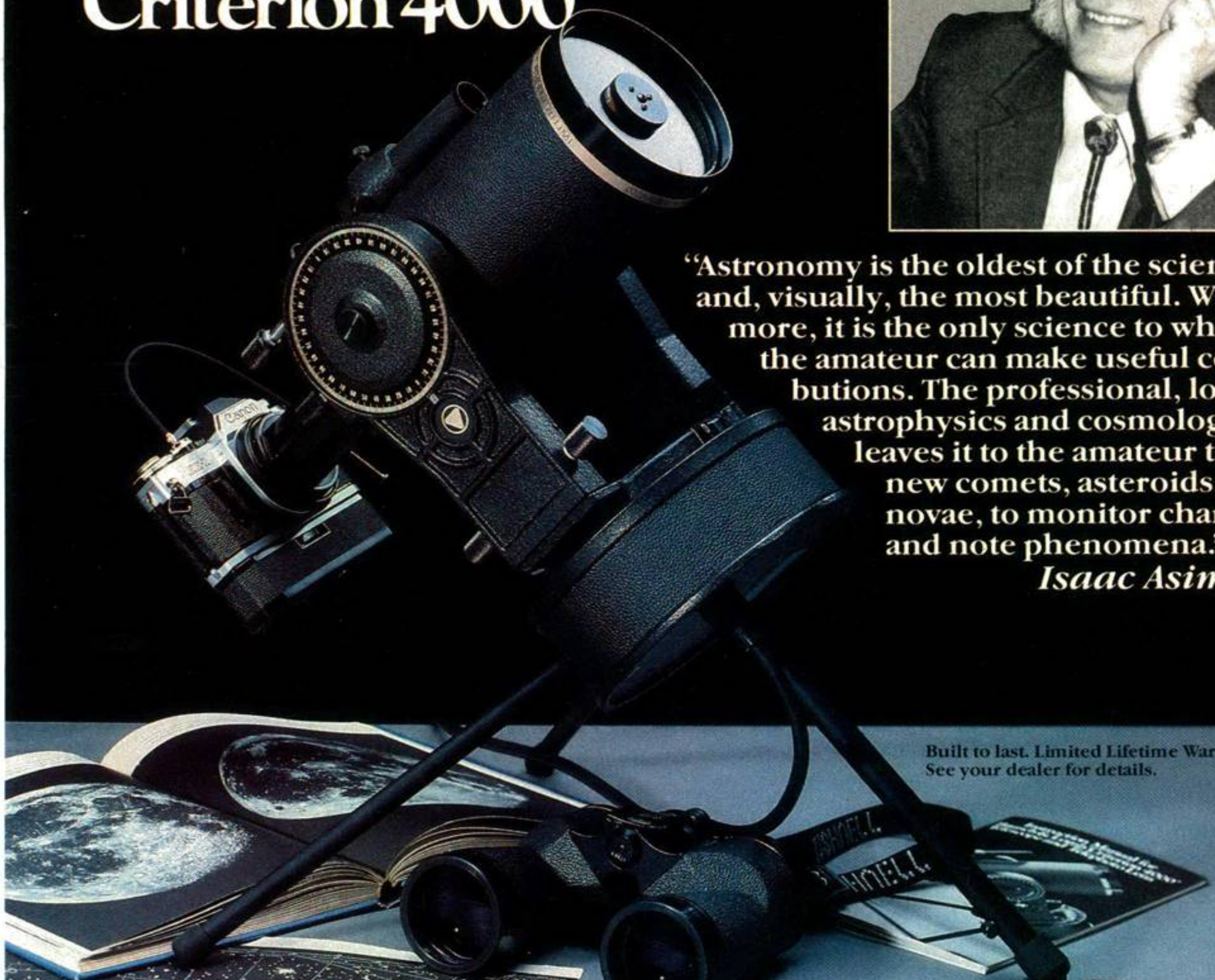

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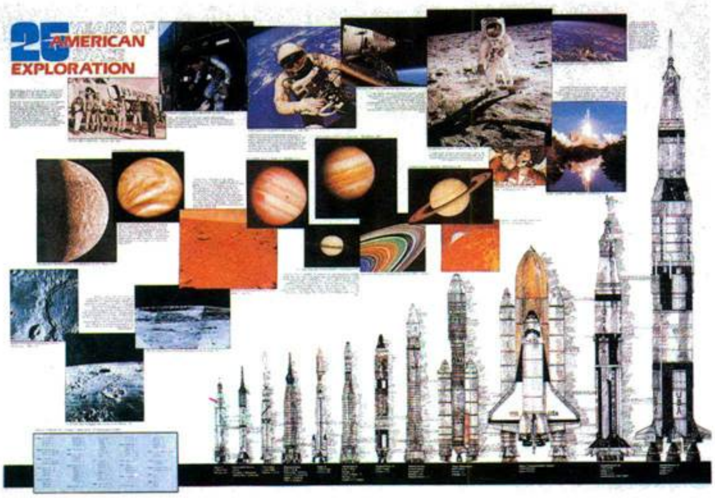

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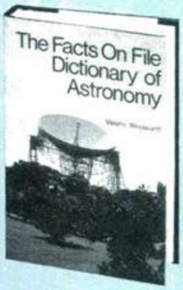

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ASTRONOMY
IN FOCUS

Hints to Observers

Sir / As a recent convert to this wonderful hobby, I was much amused by Ken Fulton's March 1983 Forum article, "Is the Universe a Harsh Mistress?" In it I recognized the full range of my own emotions as I struggled with my new acquisitions and realized I just hadn't read enough on the subject before I took the plunge. My enthusiasm almost disappeared as, week after week, I muffed my polar alignment and failed to locate my targets — seemingly easy stuff to those engaged in "Messier Marathons."

When I realized that I was actually relieved because it was too cloudy to observe, I knew I had to re-evaluate my new hobby. Trying to lift the 55-pound drive to the top of its pedestal became a nightmare. (I weigh 115.) That's when I sat down with my books, purchased some binoculars, and bought a dolly for the pedestal.

During this study period I discovered some timeless and interesting advice in the *Illustrated Science Monthly*, Vol. 11, No. 9. July 1884, published in London by Unwin Brothers. I quote from its "Hints to Observers":

"For delicate work the posture of the body must be carefully attended to. The head should be supported. Any strain will ruin all chance of seeing a minute object. The eye must be educated. Very little can be seen at first, but each year the eye becomes more and more accustomed to telescopic work."

"As regards books, *Celestial Objects for Common Telescopes*, by Rev. Prebendary Webb, is indispensible." (Prebendary = "Canon," and is, of course, the Rev. Thomas W. Webb, whose book is still in print from Dover Publications.)

"The choice of one or the other of the forms of telescope is difficult to make, since each form has powerful advocates. The reflector however is certainly the more delicate instrument to handle. Hence the refractor is far better for the beginner. Large refractors are very expensive, and our beginner cannot do better than obtain a small refractor of say 3 inches aperture, and when he has become familiar with the working of it, then he may obtain as large a reflector as he is able. Aperture is not everything however."

"As regards the mounting. Let him have a plain altazimuth stand to begin with, as he will then have to learn the stars from the maps, and will thus become familiar with the aspect of the heavens."

Sharon M. Searle
Bedford, IN

Outrageous

Sir / Although I enjoyed reading Ken Fulton's March Forum article, I must object to his suggestion that it's okay for a salesman to lie to a prospective purchaser. If my experiences have been typical, telescope manufacturers should be ashamed of their performance concerning delivery dates. And for Fulton to suggest that we should be sympathetic toward that salesman and understanding of his half-truth about the delivery of merchandise already paid for — I find it simply outrageous!

When it comes time to pay the bill — and it's usually paid at the time the order is made — no manufacturer will accept a three-to-four-month delay because the buyer must put food on the table or pay *his* daughter's dental bills. Of course they wouldn't take that excuse — and neither should an amateur astronomer who has saved and sacrificed for a telescope.

The Federal Trade Commission (Pennsylvania and 6th St., N.W., Washington, DC 20580) considers it an "unfair and deceptive practice for a mail order firm to solicit any order which the firm knows at the time of its solicitation it cannot ship within the time advertised, or where no time is stated, within 30 days of receipt of the order."

I have enjoyed Mr. Fulton's articles greatly in the past and hope to again in the future.

Jim Phillips
Charleston, NC

P.S. I purchased my first telescope in 1965, and am presently a member of ALPO and AAVSO — and yes, my first telescope was delivered six months past the date advertised and originally promised.

Save the Martians!

Sir / I am troubled by the attitude displayed in Bruce Cordell's "The First Martians" (March issue). There is a robber-baron tone to the whole piece, which reminds me of the attitudes of various oil companies or the Los Angeles Metropolitan Water District when they are confronted with environmental or esthetic questions they consider to be beyond their ken.

Cordell makes passing obeisance to the extraterrestrial-life shrine — "their recent discovery of life on Mars . . . indigenous micro-organisms found in the Solis Lacus pool" — but it doesn't match up with the last sentences of the article: "green plants will photosynthesize the carbon dioxide, releasing breathable oxygen, and taming the exotic Martian environment. Humans will then be able to stroll — unprotected — across the ruddy sands of Mars."

Hurrah — or will it all look like Bakersfield? With no elk remaining, the bird population and its swamps depleted? Just oil-mining equipment, jerry-built suburbs, cowboys in pickup trucks, and alfalfa fields? I should pay good money for you to muck up Mars, too?

If scientific surveys are only going to

look for deposits of minerals with trade potential; if we are going to plan on water-mining a desert planet without being able to understand or control water-mining here; if no wise use of Mars' natural environment is to be considered; if the word "exploit" can be used with a straight face — then I propose the immediate formation of a Tharsis Club on the lines of the Sierra Club. It looks like Mars is going to need it.

Aletha Biedermann-Wiens
Concord, CA

Binoculars

Sir / I am interested in getting a pair of binoculars for casual observing and getting to know the universe. Could you explain the difference between porro prism binoculars and roof prism binoculars? I have seen several ads for binoculars: one explains that the bigger the lens, the fainter the stars I can see. This leads me to a pair of 30 x 80s. Another explains that the lower the power, the brighter the image. So this interests me in a pair of 11 x 80s. What should I do?

Gilda R. James
Fairfield, CA

— Roof prism binoculars have a more direct, efficient light path and are lighter than porro prism binoculars. The more versatile instrument between the 11 x 80 and 30 x 80 binoculars are the 11 x 80s: with these you will experience a brighter image, wider field, and as much light gathering power as with the 30 x 80s. The lower magnification will probably be good, since you'll be able to see bigger objects and still detect the smaller ones. For additional information, see "Seeing Double" (Nov. 1982).

A Cosmic Fable

Sir / Once upon a time, there were two nations: one was strong, free, democratic, and wealthy; the other, less favored by nature, was cold, totalitarian, and far poorer. The first we shall call "Hare," the second, "Tortoise."

The first nation created an organization that, after an initial false start, forged ahead of the second in the space race. Great was the organization's prestige — "We are the guys who are putting men on the Moon," they boasted. The second, however, took things more slowly, picking its way amid jeers from patriotic hares down the tortuous paths of space technology.

However, something peculiar began happening in the first nation. Inexplicably, the space organization's funds began disappearing while its military budget skyrocketed. Scientists are still investigating this phenomenon.

They may, however, be unable to continue investigating for much longer. Hare's space organization is floundering. No help seems forthcoming from the government, interested only in the military, while the President's knowledge of space terminates with his hobby-horse — satellite-mounted laser weapons. This politician, whom we shall refer to as "President Ray-gun," is now proposing the complete clipping of the space organization's planetary exploration wings.

Meanwhile, the tortoises orbiting overhead in a Salyut space station must be laughing their shells off.

Chris Boaden
Sydney, New South Wales
Australia

Ooops!

On page 43 of the May issue, the photo credits were reversed.

The following replaces the final paragraph of column 2, page 19 of the July issue:

Although not overluminous at visible wavelengths, M-87 is extraordinarily bright in both the X-ray and radio regions of the spectrum. The core of this ten-trillion-sun galaxy emits 5,000 times more X-ray energy and 2,000 times more radio energy than a galaxy such as our own.

behind the scenes

watching the comet

Here at ASTRONOMY, we first heard about Comet IRAS-Araki-Alcock the night before the news appeared in the papers. Dave Eicher called me — a little before midnight — with the new comet's coordinates. I plotted its position on *Sky Atlas 2000.0*; 20 minutes later I was looking at it through the portable telescope from May's Equipment Atlas. The comet was dim, but I knew it was going to get much brighter.

We spent Thursday trying to get more information about it. From the ephemeris, it was obvious that the comet would be long gone before we could publish a word about it in ASTRONOMY. By the next day — Friday — we felt that we had collected as much information as we were going to get, so Dave and Frank Reddy, our enthusiastic new editors, alerted the local radio and TV stations. Meanwhile, of course, heavy clouds rolled in for the weekend.

But mid-Sunday, the sky cleared. A few phone calls later, Greg Walz-Chojnacki, ODYSSEY's Assistant Editor, and I had agreed to drive north of the city for a better view. I threw a few cameras and a telescope in the back of my van, added Greg's 8-inch reflector, and off we went. Greg and I arrived at dusk at a little parking area on a dead-end road 20 yards from Lake Michigan; we set up our scopes as the sky darkened. Just as I was about to get out the atlas, Greg said, "Richard, what's that?" I looked where he was pointing: there was the comet in the coils of Draco, easily visible to the naked eye. I made sketches, Greg took pictures; we looked and looked at this pale apparition, already brighter than M-31. Greg's 8-inch reflector at 40x showed the extensive coma; my 6-inch refractor showed the tiny starlike nucleus and inner fan-shaped coma especially well.

Monday was a circus. Lots of ASTRONOMY's readers called for information. We read the ephemeris over and over, and gave several phone interviews to local radio stations. And the sky stayed clear. That night we drove back to our little dark-sky site with ten people from AstroMedia and five telescopes. The comet was bright and moving fast — watching it move was like watching the minute hand of a clock — near Kochab in the Little Dipper. We also turned the telescopes on Venus, Saturn, a variety of Messier objects, and finally Jupiter, too.

Tuesday was worse. More phone calls. More radio. Dave did a TV interview. And the sky stayed clear. On that third night, our dark-sky site seemed three million miles away rather than a mere 40. Still, we went. . . .

Sincerely,

Richard Berry

Richard Berry
Editor

gazer's
gazette

a shot out of the dark

As most really exciting astronomical events do, it came like a shot out of the dark. On May 4, at about 9:00 p.m., I received a phone call from a friend at Lowell Observatory who had astonishing news: the fast-moving solar system object detected by IRAS on April 25 was not an asteroid, as the IRAS crew had originally thought. It was a comet — already shining at sixth magnitude and expected to reach second — which would be visible almost all night for the first two weeks of May. My friend told me that Japanese amateur Genichi Araki had discovered the comet just 36 hours earlier. A few hours after Araki's sighting, George Alock independently picked up the patch of light in England. So according to International Astronomical Union protocol, the comet — known as 1983d — became Comet IRAS-Araki-Alcock.

Great galloping galaxies! For the first time since Comet West in 1976, we would see a fine naked-eye comet. It's about time, I thought to myself, having been left relatively unimpressed by comets Kohler, Bradfield, Machholz, Meier, Panther, and Austin. After all, Comet West was one of the glorious sights that convinced me to get deeply involved in observational astronomy. But after these momentary cynical thoughts — mixed with pure glee — my friend's voice broke back in. "And you know what's really interesting about this," he said, "astrophysically it's a small comet." It took but a split second to figure him out. If it's a tiny comet but very bright, then it must be scheduled to pass *extremely* close to Earth. He broke back in again: "It'll miss us only by 2.88 million miles and be the closest approach of a comet to Earth since Lexell in 1770." Whew, I thought. Saved by 3 million miles from a collision with an Oort Cloud projectile.

After getting a preliminary set of positions, I dug out my comet plotting atlas and marked it up some more. I drove out of Milwaukee to a fairly decent observing site, set up my scope in record time, and started searching. My excitement — and a slight bit of haze — kept me from instantly finding the fuzzy glow, but after a few minutes of scanning, it showed up. I sketched it, recorded its position in northern Cygnus, estimated its magnitude at 6, noted its unusual fan shape and stellar nucleus, and drove home.

MAY 10: John Gianforte photographed IRAS-Araki-Alcock on May 10.1 UT.

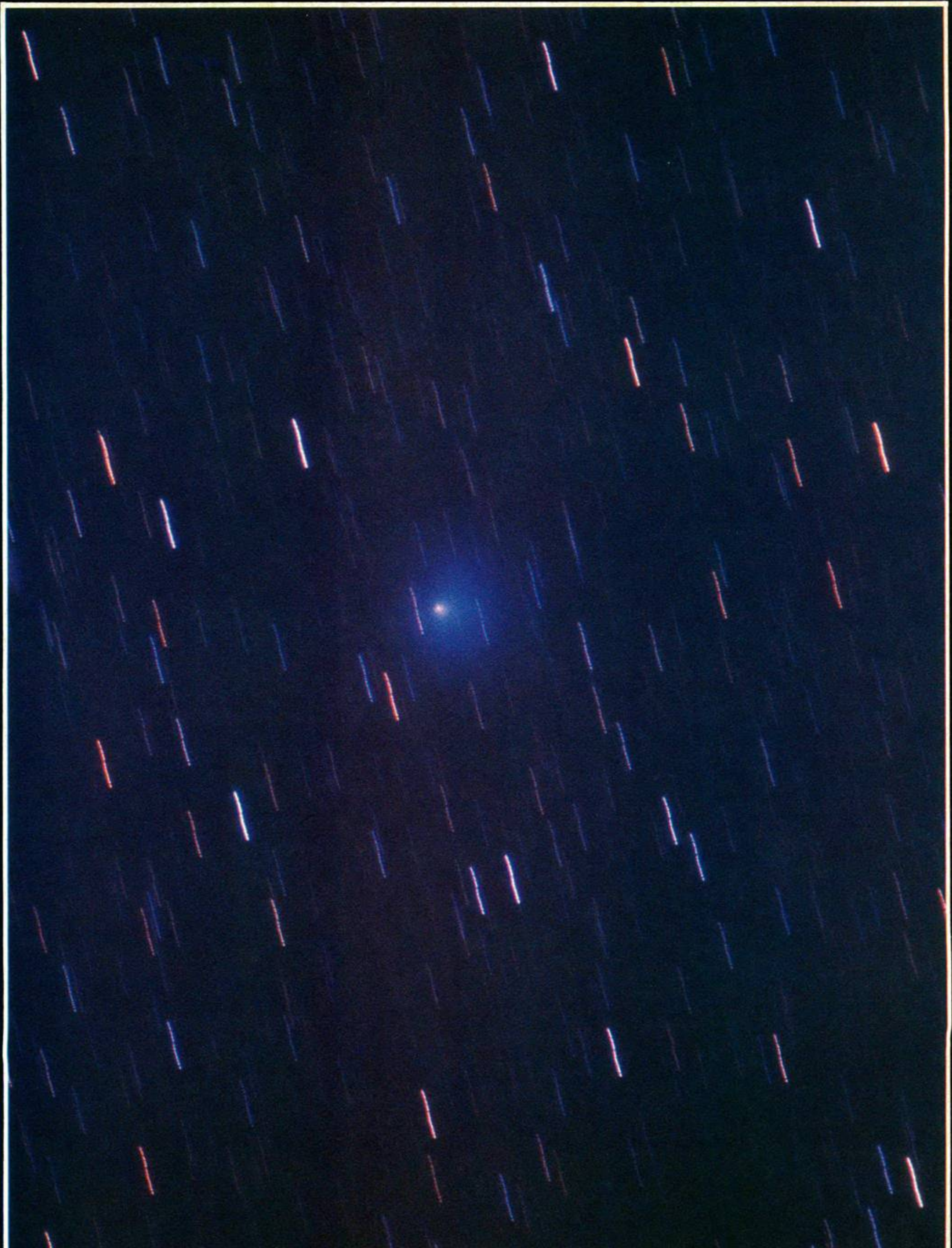
Since the comet was due to pass so close to us, it would be moving very fast across the sky. The next night (the 5th) it skipped over the border into Draco and grew somewhat larger and brighter. But the minimum value of "delta" wasn't due until May 11.5 UT — May 10 at 8 a.m. EDT — still five days away!

The comet displayed a unique fan-like structure pointing *toward* the Sun; this was probably the visual effect of seeing "streamers" pointing toward the Sun that actually — as they grew fainter — wrapped outward, arching away from Sol. The nucleus was off-center in the coma and appeared to be starlike. I couldn't help but be amazed that I was looking at a tiny comet's solid center. There was no sign of a tail.

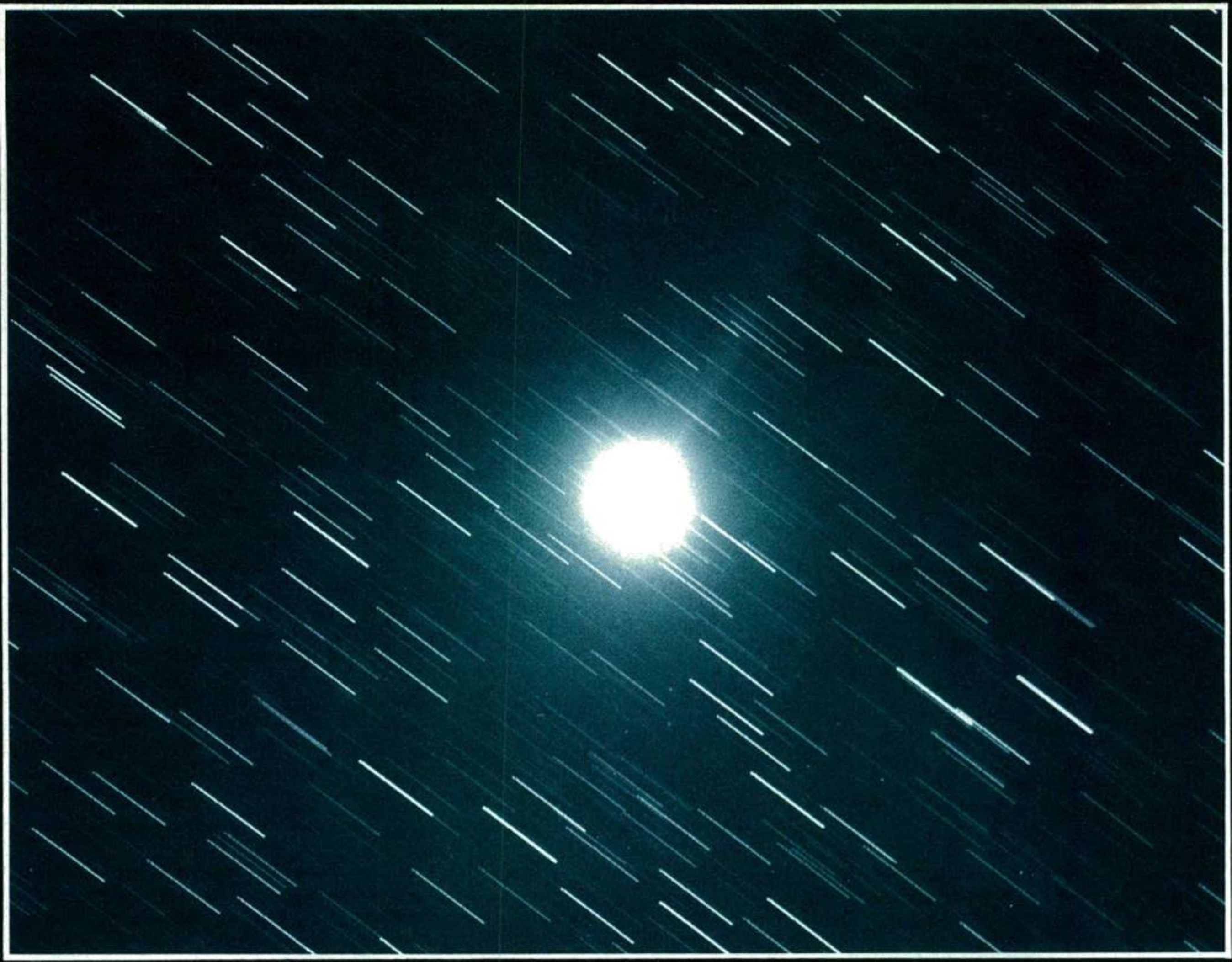
On the 6th, IRAS-Araki-Alcock brightened considerably — perhaps to fifth magnitude — and became a fine naked-eye sight. It rested under the line of stars formed by Zeta (ζ), Eta (η), and Theta (θ) Draconis, and appeared — without optical aid — to be elongated. The best views came through binoculars and finderscopes: the large, hazy coma measured over a degree across, and waiting even a few minutes allowed observers to detect the comet's motion across the sky. This object was undoubtedly the fastest mover ever observed by many backyard observers, bar none (excluding space hardware, folks).

For the next two days the comet brightened, bound on a journey through Draco, heading straight for the bowl of the Little Dipper. Now it shone at fourth magnitude, and you could take friends out who never heard of comets and show them one. An 8-inch scope revealed a field full of nebulosity, subtle "jets" fanning out from the nuclear region, and of course the tiny nucleus. A 12-incher showed pretty much the same picture, but with slightly better resolution. I still opted for finderscope views: in my 6x30 I saw what appeared like a big galaxy with a slight central condensation and a faint mottling around the core.

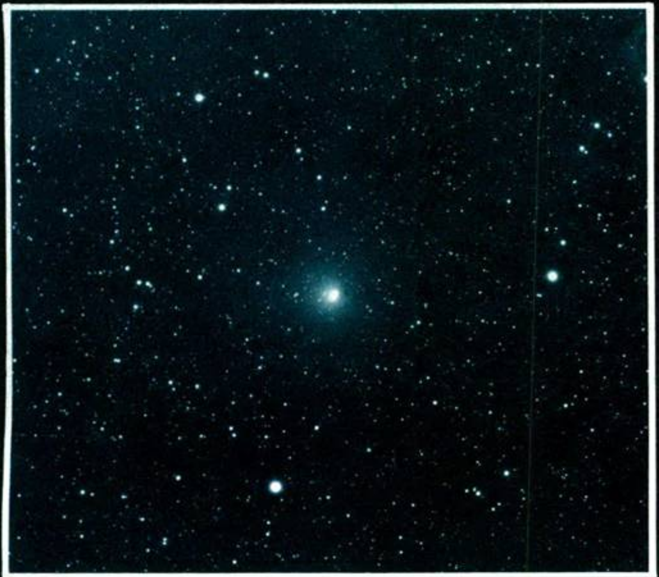
By the 9th of May, the comet grew brighter than third magnitude. Its encapsulating envelope of gaseous material spanned 2°, practically obliterating the equally bright star Kochab



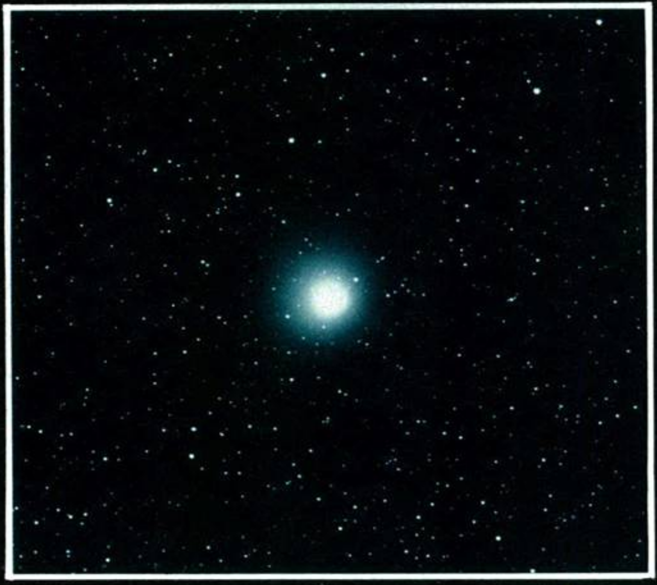
MAY 12: On May 12.2 UT Brad Wallis and Robert Provin made this fine photo by guiding on the comet's nucleus. It is a 15-minute exposure on 400 ASA film, made with a 135mm f/2.8 lens.



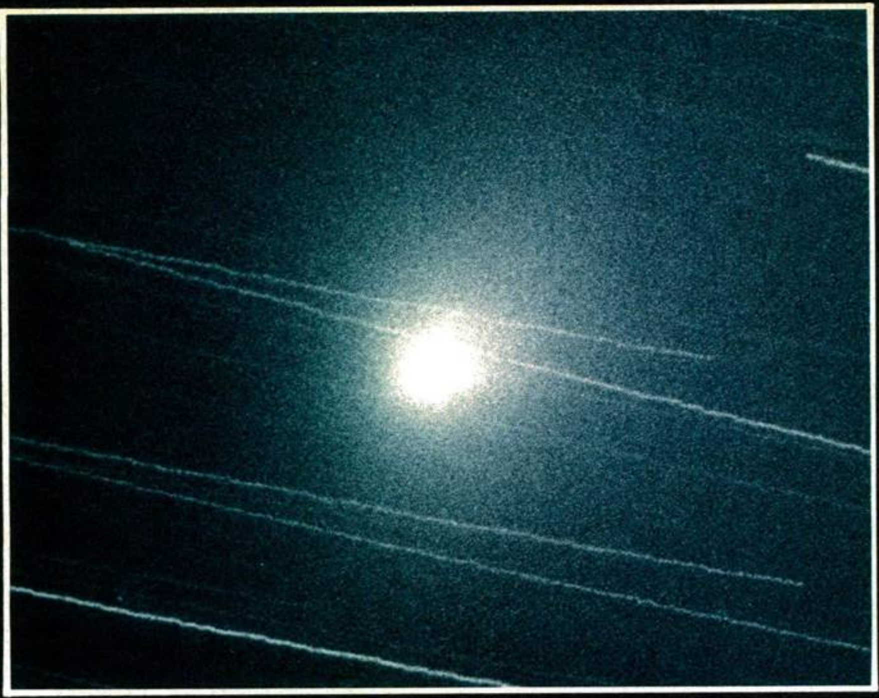
MAY 10: On the evening of the 10th, Donn C. Reiners and Dean Essenmacher recorded IRAS' faint gas tail. They used an 8-inch f/1.5 Schmidt Camera, hypersensitized TP 2415 emulsion, and a 5-minute exposure.



MAY 5: This image shows the comet's appearance on May 5.0 UT, just over a day after its discovery by G. Araki. Lowell Observatory photo by Brian A. Skiff.



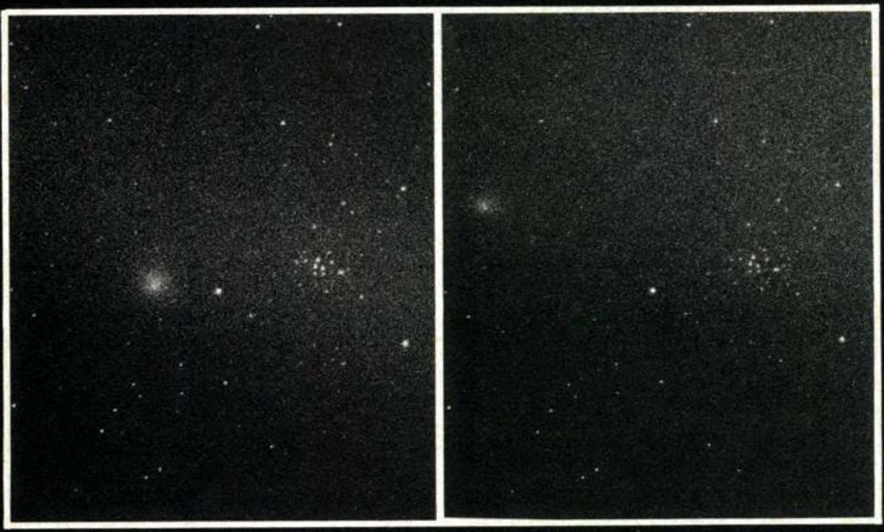
MAY 7: On May 7.2 UT John Kielkopf and Alan Goldstein recorded the comet using a 14-inch f/1.7 Schmidt Camera. Moore Observatory photo.



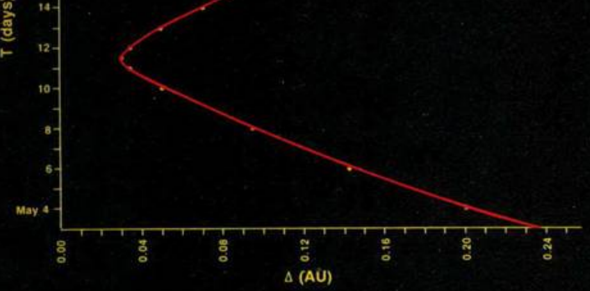
MAY 10: At the Jet Propulsion Laboratory's Table Mountain Observatory, James W. Young photographed IRAS-Araki-Alcock on May 10.2 UT. NASA photo.

MAY 10: Donn C. Reiners and Dean Essenmacher imaged IRAS on the 10th.

MAY 11: Jacques Guertin made this photo of IRAS' tiny nucleus on May 11.2 UT.



MAY 12: IRAS-Araki-Alcock was the fastest moving sky object in the last 200 years. Bill Smith and Daniel Marcus took these two photos 1h 20m apart; in each case, they exposed Tri-X for 1 minute using a 50mm f/1.7 lens.



This dramatic curve represents the comet's distance from Earth (Δ) over the first part of May.

in the bowl of the Little Dipper. A team of observers from AstroMedia took an expedition northward to dark skies; they watched as — within minutes — the glow approached, passed, and left the star behind: "It's like watching the minute hand of a clock," said Richard Berry.

But it was the next night, the 10th, that really paid off. Local and national news reports jumped on the story, most with the naive alarm that accompanied comet appearances 1,000 years ago. Having found out what a comet is, one reporter instantly asked me, "Are we in immediate danger of a collision?," his face aglow at the thought of getting a "scoop" on the end of the world. I reassured him that although three million miles is close — only 12 times farther away than the moon — it's still a long hike.

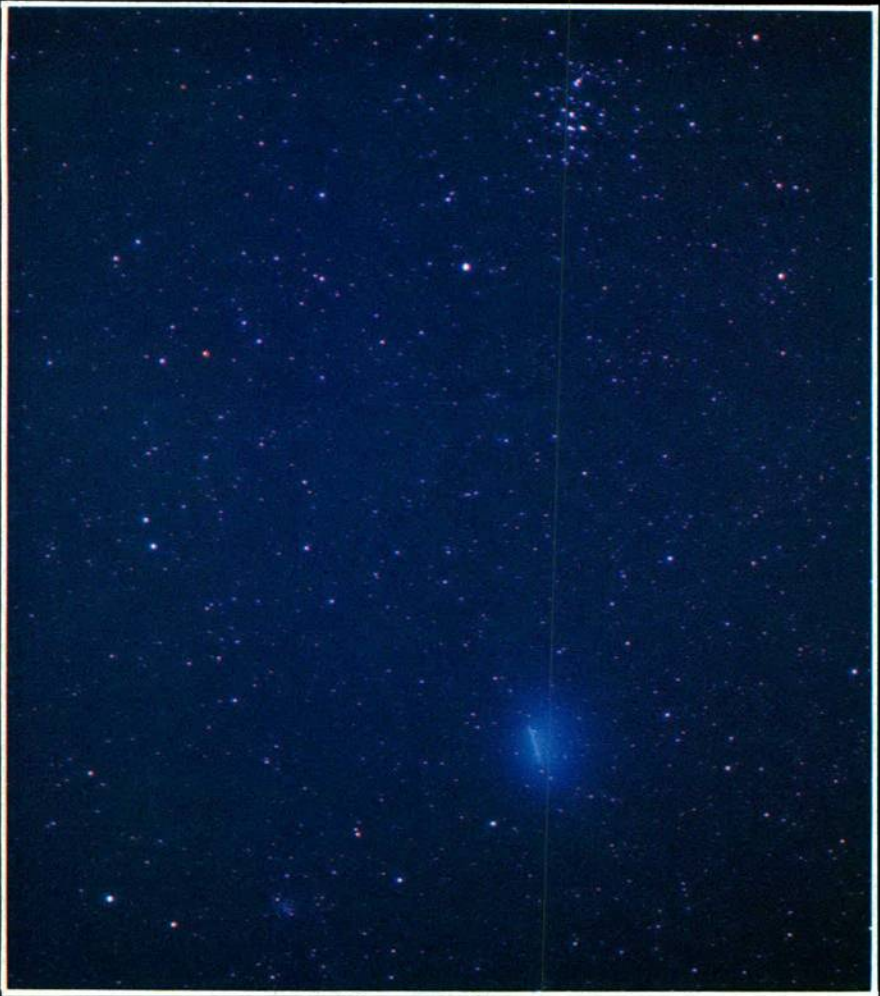
Observers and astrophotographers were hard at work everywhere. At the Milwaukee Astronomical Society's observatory, countless bodies seemed to be running every which way, screaming about getting the film loaded and the scopes polar-aligned. At ASTRONOMY, we were already receiving lots of photos of the comet.

The comet didn't seem to change its shape or overall appearance radically from the past couple of days: it just got brighter, as though someone were turning on a light behind an image of the thing. It was a subtle glow, however, but one capable of thrilling anyone who took the time to see it from a dark sky. It now formed a wide, more-or-less equilateral triangle with the bright stars Dubhe and Merak, the end stars belonging to the bowl of the Big Dipper. With unaided eyes, it looked like a very bright elongated spike, almost reminiscent of a super M-31.

Having now passed its closest approach to Earth, IRAS still whizzed across the sky at an unbelievable rate of 40°+ per day. My friend at Lowell Observatory told me that astronomers using the 42-inch reflector on Anderson Mesa actually had to tape down the "fast" button on the guiding unit to successfully track the celestial visitor. It would now rapidly fade and move southward as it approached perihelion. Going home on the morning of the 11th, I knew we already had our best looks at the Great Comet of 1983.

But still it remained visible, although not as impressive. On the night of the 11th, the comet had already moved down into Lynx, quickly approaching the Sun's position in the sky. It was now a third-magnitude object — still large, but no longer high in the sky where it could be viewed nearly all night. During the next two nights, IRAS closely passed by the Beehive Cluster (M-44) in Cancer, dimmed to magnitude 3.5, practically overran open cluster M-48 in Hydra, dwindled some more, and sank below the horizon into Puppis. The show ended almost as fast as it had started.

— *David J. Eicher*



MAY 12: Toward the end of the show, IRAS-Araki-Alcock passed close to star clusters M-44 and M-67. On May 12.2 UT, Brad Wallis and Robert Provin used a 135mm f/2.8 lens, 400 ASA film, and a 15-minute exposure.

IRAS-Araki-Alcock: An Ephemeris

Date (UT)	R.A. (1950)	Dec.	Distance (AU) from		Mag.
			Earth	Sun	
Apr 25.9	19h 06m	+48° 39′			
27.9	19 05	+49° 18′			
May 2.5	18 58	+51° 44′			
3.6	18 56	+52° 30′			7
3.9	18 55	+53° 02′			6.5
4.2	18 53	+53° 24′			6.0
5.0	18 50	+54° 22′			5.7
6.0	18 44	+56° 02′	0.143	1.025	5.4
7.0	18 34	+58° 21′			5.0
8.0	18 16	+61° 45′	0.095	1.017	4.5
8.5	18 01	+64° 04′			4.2
9.0	17 36	+66° 58′	0.071	1.013	3.8
9.5	16 51	+70° 27′			3.4
10.0	15 20	+73° 41′	0.050	1.010	3.0
10.5	12 42	+72° 36′			2.6
11.0	10 30	+61° 33′	0.034	1.007	2.2
11.5	09 23	+42° 09′			2.1
12.0	08 49	+21° 12′	0.034	1.004	2.0
12.5	08 29	+04° 39′			2.5
13.0	08 16	−06° 41′	0.049	1.001	3.0
14.0	08 00	−19° 35′	0.070	0.999	3.7
15.0	07 51	−26° 15′	0.093	0.997	4.3
16.0	07 45	−30° 11′	0.118	0.995	4.8
17.0	07 41	−32° 53′			5.2
18.0	07 38	−34° 41′	0.167	0.993	5.6
19.0	07 35	−36° 00′			5.9
20.0	07 34	−37° 01′	0.217	0.992	6.1
21.0	07 32	−37° 49′			6.6
26.0	07 27	−40° 11′	0.365	0.995	7.3
31.0	07 24	−41° 18′			7.9
June 5.0	07 22	−41° 59′	0.604	1.024	8.5
10.0	07 21	−42° 26′			9.0
15.0	07 20	−42° 49′	0.826	1.079	9.4
20.0	07 20	−43° 10′			9.8
25.0	07 20	−43° 32′	1.028	1.155	10.2

ASTRONOMY
REVIEWS

Pictorial Astronomy, fifth revised edition
Dinsmore Alter, Clarence Cleminshaw, John Phillips
374 pages, hardbound, $19.95
Harper and Row (1983)

Since 1948, *Pictorial Astronomy* has been one of the better comprehensive introductory-level books in the field. Despite its title, it is not a showy coffee-table ornament, long on surface glamour and short on substance. Instead it has earned the reputation of being a reasonably complete, though general, introduction to the solar system and beyond. The crisp, highly readable text has introduced many to the delights of astronomy. The many tables, illustrations, line drawings, and graphs that serve to amplify various theories and concepts have been pertinent. The earlier editions of this volume were purposeful and enlightening; like the present revision, their price was reasonable.

The book has also always boasted an unusual number of clearly reproduced black and white photographs, and the present edition is no exception — although many of the photographs will be familiar to most astronomy buffs. The latest edition has 46 more pages than the previous (1974) version. It retains its eight color pages, but the photographs have been slightly reduced in size to accommodate an additional seven excellently reproduced plates. Earlier revisions were fairly extensive and included accurate, up-to-date information. In the introduction to the new revision, the author who revised the book writes, "The fifth edition of *Pictorial Astronomy* has been extensively rewritten to include all the most recent discoveries."

However, all this notwithstanding, the current edition falls far short of the mark. Though some new material is included, a side-by-side comparison with the 1974 edition brings to light some glaring inconsistencies.

A significant amount of text has merely been transplanted from one part of the book to another. For example, the chapter "Exploding Stars" has been moved from its previous location, but the text and photographs are unchanged — no revision, just a juggling of material. Such superficial "revision" is true of several chapters. Another instance: the fourth edition's chapter "The Galaxies of Space" has been split into one chapter with the same name and a new chapter entitled "The Galaxy Around Us." Again, much of it is the same material under a different name and placed somewhere else in the book. The earlier "Radio Astronomy" chapter has been converted into "The Mystery of the Quasars" plus another, rather abbreviated, chapter entitled "Radio Astronomy." But there has been only a minimal amount of new information added. I get the feeling that the alterations are little more than change for the sake of change.

The present edition also shows evidence of careless editing. In the previous edition, a section titled "Photographing the Planets" states, "The photographs on page 107 disprove this idea." (The reference is to the belief that only the largest telescopes can produce good photos of the planets.) The new edition also has the statement, but on turning to page 107 to see the photograph, the reader instead finds a line drawing of the solar eclipse of 1937. The photo in question appears elsewhere in the book, apparently having been shifted without anyone catching and correcting the text reference to it. And, again, the reader finds no new material, just a reshuffling of the old.

Slipshod editing aside, this new edition would have been consistent with the earlier editions if it had received an infusion of accurate and current information. Unfortunately, a careful reading indicates lacks in this area also. Let's say you want to know about the Space Shuttle. On turning to the index, you discover that there is no entry under either Shuttle or STS, but there is one for Space Plane. Turning to the indicated page, you find an artist's rendering of a craft that resembles the Shuttle. A few pages later, the text says "By 1982 McDonnell Douglas will be conducting pharmaceutical experiments" on the Shuttle. Hardly an up-to-date observation!

The rotation speed of the Sun, according to the book (and apparently lifted from the earlier edition) ranges from 25 to 35 days from pole to equator. Modern figures place this in the 27 day range.

Concerning our own planet, we find on page 26 that "the equatorial diameter is 27 miles longer than the polar diameter." Then on page 58, we discover that the terrestrial girth has decreased and the "diameter at the equator is some 26 miles greater than its diameter from pole to pole."

The caption under a photograph of the 200-inch telescope at Palomar reads "This is the largest telescope in the world." Yet on the following page we read, "The largest telescopes currently in operation are the 236-inch telescope at the Crimea Observatory...." with no further mention of the 200-inch giant.

These errors and inconsistencies are not isolated instances. Had the publishers made a more thoughtful and careful attempt at updating this volume, and had they insisted on accuracy and detail, this fifth edition of *Pictorial Astronomy* would have matched the high quality of its predecessors. Unhappily, it does not. Should it reach a sixth edition, I hope the book gets the meticulous updating it needs. *Gail O. Clark.*

The Greatest Adventure
Narrated by Orson Welles
Produced and Directed by Steve Sabol
Laser Videodisk, 49 minutes, $29.95
NFL Films, 1979
Released by Vestron Video (1983)

Owners of laser videodisk players can rejoice in the recent NASA-authorized release of several "space disks" that contain an enormous amount of material. The Apollo disk, for instance, covers lunar missions 11 through 17 and includes more than 10,000 NASA still photos on freeze-frame. Since the laser videodisk is played with a microscopic beam of light striking the disk, there is no wear whatsoever and you can hold a single frame on the screen practically forever. Unfortunately, these disks aren't cheap: they cost over \$300 apiece.

For the astronomically minded person of more modest means, Vestron Video has released a 1979 television documentary on the Apollo flights for a tenth of the price. However, the old saying, "you get what you pay for," comes into play with a vengeance. *The Greatest Adventure* is a popular treatment, intended for a non-technical audience, and sacrifices accuracy — and even dignity — for entertainment purposes. Moreover, the disk was recorded in long play mode as opposed to the standard play, which for technical reasons means that most of the laserdisk's special features (like freeze-frames) are inoperative — Vestron's disk just plays from one edge of side 1 to the other, and side 2 is blank. (The video cassette owner who buys *The Greatest Adventure* on tape can use slow motion, freeze-frame, and fast-forward however he chooses.)

The Greatest Adventure is ably narrated by Orson Welles, and one of the documentary's best moments comes when he recites the poem "High Flight" against NASA footage of spacewalking Gemini astronauts. But poor Orson could only make the best of what he was given, and the script is where the story runs into trouble. In its attempt to compress the entire lunar program from 1961 to 1969 into less than an hour, it glosses over important points, leaves others out entirely, and often turns what's left into hopeless confusion.

The Greatest Adventure opens with President Kennedy's speech of May 25, 1961, pledging to put a man on the Moon by the end of the decade. It then cuts back to the beginnings of Project Mercury and the selection of the original seven astronauts in 1959, without ever making the chronology clear. Younger viewers could easily assume that the entire space program began as a result of JFK's decision. Reasons why we should go to the Moon are vaguely referred to in terms of the Russians throwing down a gauntlet, with no direct mention of Sputnik in 1957 or Yuri Gagarin's 1961 flight — or Kennedy's personal humiliation in the Bay of Pigs fiasco, for that matter. The fact that the Russians orbited a man first gets mentioned only in passing when the documentary covers John Glenn's flight.

Other important chapters in the history of spaceflight, such as Goddard's experiments with liquid-fuel rockets, the German military rocket effort at Peenemunde, and postwar American research at White Sands, aren't so much as mentioned. Their omission is particularly glaring when Wernher von Braun shows up for a moment well into the story and the small fry in the audience are left wondering who he is and why he's so important.

In fact, the central problem of *The Greatest Adventure* may be that the viewer is expected to know too much already. But as the events chronicled recede into the past, young people who weren't even born at the time are growing up and taking an interest in things extraterrestrial. They are sure to come away from *The Greatest Adventure* more confused than when they started. The purpose of the Gemini flghts and where they fit into the scheme of things are never made clear. The Apollo 8 lunar flight gets considerable coverage, but nowhere is it explained what it was supposed to accomplish or why it didn't land.

The documentary is further hurt by an all-pervading air of hokiness. It's *corny* — often to the accompaniment of preposterously overdone music. When Neil Armstrong steps off the ladder onto the Moon, he's greeted by stirring music and a throaty chorus that might be a little much for the Second Coming itself. There are also arbitrary dramatic cliffhangers, placed just before what must have been commercial breaks in the original television presentation. ("The Saturn-5

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rocket . . . the six million pound machine . . . but would it fly?" CUT!)

Yet having said all that, I found *The Greatest Adventure* does have its merits. Besides a generous use of official NASA footage of astronauts and rocket launchings, it also has interviews with such notables as Alan Shepard, Eugene Cernan, author Tom Wolfe — even (briefly) Neil Armstrong himself. Wolfe's comments on Apollo 8 are particularly interesting; they hint at the things that might have been in *The Right Stuff* had Wolfe gone ahead with his original plan, which was to cover the entire space program through Skylab.

The Greatest Adventure will be useful for giving Junior a quick and breezy overview of the massive American enterprise that put a man on the Moon nearly 15 years ago — but you ought to have some authoritative books on hand to correct any misapprehensions. If it's historical accuracy and scientific value you want, start saving for the NASA disks now. *Dwight R. Decker.*

Atoms in Astrophysics
P.G. Burke, W.B. Eissner, D.G. Hummer, and I.C. Percival, eds.
356 pages, hardcover, $49.50
Plenum Press (1983)

Colleagues and former students of Michael Seaton prepared this volume of scientific papers to mark his sixtieth year. Seaton became well known as one of the few people who understood both the detailed methods for calculating atomic data and the astrophysical requirements of such data. The book's contents reflect Seaton's prodigious influence on the subject of atoms in astrophysics. Planetary nebulae, forbidden atomic lines in aurorae, electron-ion processes in hot plasmas, and proton impact excitation of positive ions are among the topics discussed.

Internal Kinematics and Dynamics of Galaxies
E. Athanassoula
432 pages, hardcover, $49.50; paperback, $26
Reidel (1983)

Just what makes galaxies tick? Are density waves the culprits responsible for spiral arms, or are supernova shockwaves more important? What are the effects of galactic mergers? Are axially symmetric disk galaxies the exception rather than the rule? This volume contains papers presented at IAU Symposium No. 100 in Besancon, France, in 1982. Spiral structure, the kinematics of gas and the underlying mass distribution, barred galaxies, spheroidal systems, mergers, and galaxy formation are the sections into which the book is divided.

The question of the existence of massive haloes around spiral galaxies is widely debated today, and this book presents many new results on spiral amplification, modes, and barred galaxies. It also reports on the influence of mergers on the evolution of galaxies, and some interesting results of galactic "triaxiality."

Kinematics, Dynamics, and Structure of the Milky Way
W.L.H. Shuter, ed.
392 pages, hardcover, $54.50
Reidel (1983)

Galactic astronomy is presently in a state of turmoil. Observational astronomers are busily accumulating a wealth of new data, often from gamma radiation or submillimeter waves — previously inaccessible regions of the electromagnetic spectrum. Meanwhile, theoreticians are developing new techniques and perspectives that are not only being applied to this new information, but are helping to re-evaluate previously collected data.

This volume contains papers from a workshop on the Milky Way held in Vancouver, Canada, in 1982. New data and ideas have emerged — important to astronomers attempting to create a coherent picture of our home Galaxy.

Advanced Technology Optical Telescopes
Geoffrey Burbidge and Larry D. Barr, editors
450 pages, softcover, no price given
SPIE — International Society for Optical Engineering (1982)
[address: P.O. Box 10, Bellingham, WA 98227]

What will the ground-based telescopes of the late 20th and early 21st century be like? They're being planned right now. This thick book, the 332nd Proceedings of the SPIE, very likely describes that future. The spectacular success of the Smithsonian/University of Arizona Multiple Mirror Telescope has all but guaranteed that they'll be alt-azimuth mounted and computer controlled — giant Dobsonians — and many will contain "active optics" to undo the damage done by Earth's atmosphere. The papers are quite technical.

Stellar and Planetary Magnetism
A.M. Soward
370 pages, hardcover, $46.75
Gordon and Breach (1983)

This volume contains professional papers from a workshop on planetary and stellar magnetism held in Budapest, Hungary. The book discusses dynamo theory, solar magnetism, geomagnetism, and compositional convection.

Celestial Objects for Common Telescopes
by T.W. Webb

Over the years, *Webb's* has been a treasured source for thousands of observers. This classic covers the solar system in Volume 1, and deep-sky objects (grouped by constellation) in Volume 2. Valued as much for its style as for its content, *Webb's* is a book for every telescope owner.

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eye on the sky

venus enters the morning sky

by Fred Schaaf

the wanderers

This month Venus makes a dramatic departure from its long tenure as Evening Star. August is also the month when naked-eye observers can perform a valuable service by monitoring the Perseid meteor shower. Will this year's shower feature a spectacularly enhanced peak (up to 100 meteors per hour) that could herald the approach of its great parent comet?

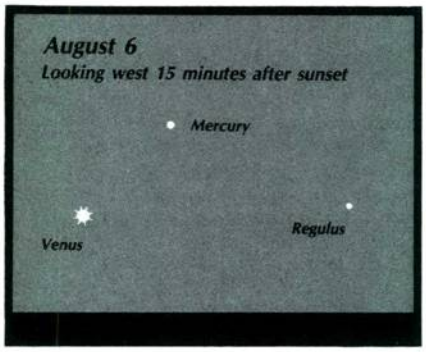
In the last three weeks before inferior conjunction, **Venus** approaches ever closer to us and our line of sight with the Sun. Thus Venus loses about a degree of elongation each day and nearly a full magnitude of brightness during the entire period. It is sometimes possible to observe Venus after sunset with the naked eye when its elongation from the Sun is well under 10° — providing the planet is located almost vertically above the Sun. This evening exit of Venus will be far from that ideal situation.

One problem is a familiar one: the ecliptic angle is very shallow in the evening sky at this time of year. Also, Venus is currently almost as far south of the ecliptic (and, at inferior conjunction, the Sun) as possible. Australians will have an excellent chance to observe every day of Venus's passage from evening to morning sky. In North America and Europe, Venus will be *combust* (invisible around the time of conjunction with the Sun) for several weeks — almost the longest period possible.

As August starts, Venus is still a -4 magnitude object, setting well over an hour after the Sun for viewers at 40° north latitude. By the 12th Venus is setting no more than 30 minutes after the Sun, and *on the 15th and 16th* the two set simultaneously, even though Venus still lies east of the Sun on the celestial sphere. By the 24th, the day of inferior conjunction, the planet sinks below the horizon more than a half hour before the Sun. What is the last date you can see it with the naked eye? With binoculars?

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

Venus is 8° south of the Sun at this inferior conjunction. This is almost the farthest possible because the planet reaches its greatest latitude south of the ecliptic just 10 days later. The ecliptic is the plane of Earth's orbit projected onto the sky (where it becomes the apparent path of the Sun through the constellations). But how is it possible for Venus to depart so far from the ecliptic? The orbits of some planets are more tilted than others relative to Earth's. In fact, Venus's orbit is the third most highly inclined, with a tilt of 3.4°. Mercury's orbit is, however, more highly inclined. Why, then, can Venus depart even farther from the ecliptic than Mercury, more than 3.4°?



The answer lies in the fact that Venus can come very close to Earth; a lesser factor is Mercury's smaller orbit. The 3.4° inclination causes a greater displacement on the celestial sphere when Venus is closest to us, which always occurs near inferior conjunction. This time, Venus is closest to Earth on August 25, when it is only 0.29 astronomical unit (AU) from us. The two planets can approach even closer; although Venus is at aphelion on August 12, Earth is far from perihelion this month.

The ascension of Venus into the morning sky after inferior conjunction will be comparatively swift, aided by the ecliptic's steeper angle to the horizon. Venus will be a faint -3.1 magnitude on the 24th. Can you find Venus as a -3.5 point of light on the morning of the 31st, rising just a half hour before the Sun? The following mornings will be better, and in next month's column we'll discuss a new plan for finding Venus's crescent with little optical aid — or even none at all!

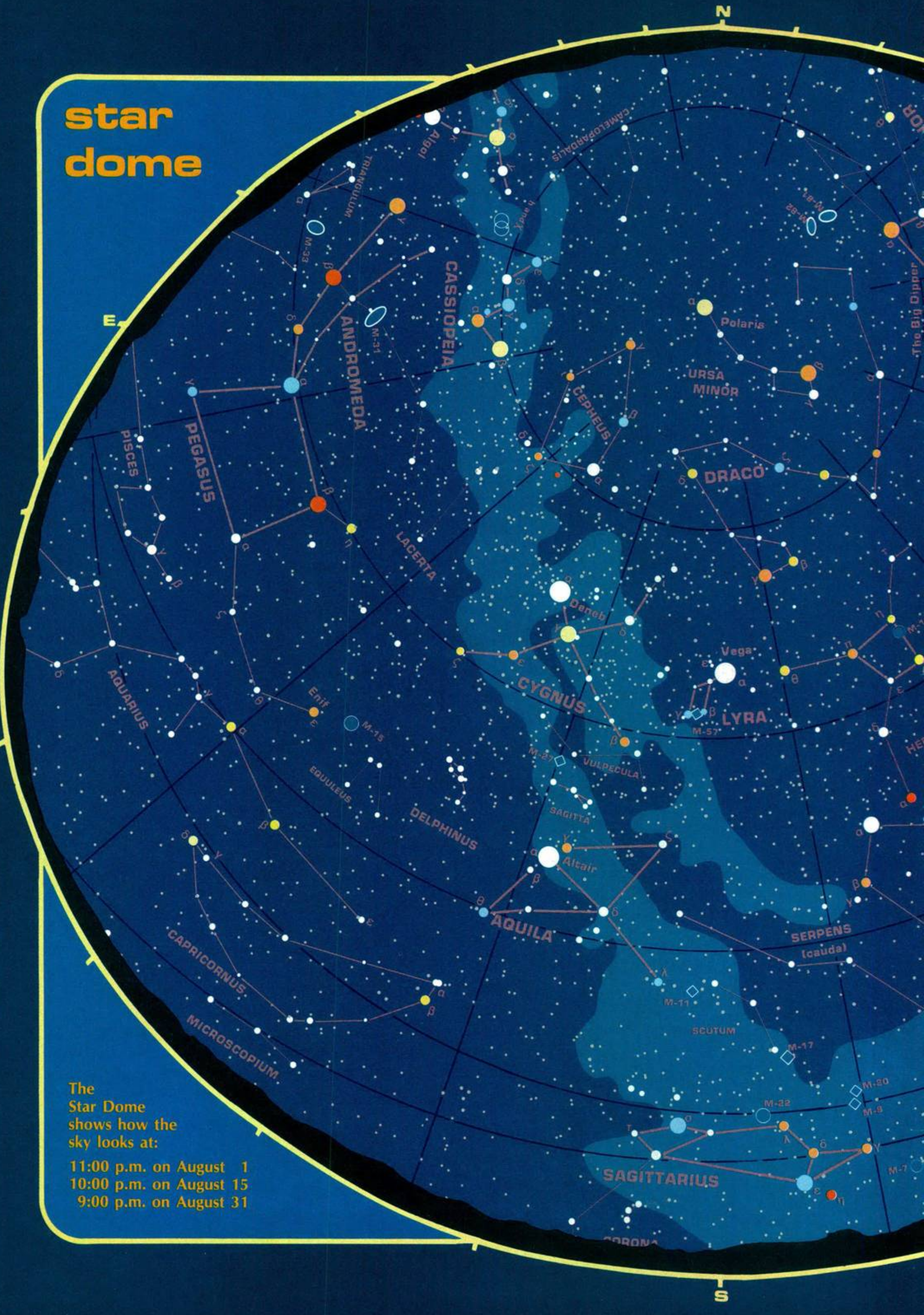
The planets Saturn, Jupiter and Uranus remain easily available for observation in August. **Saturn** continues to move away from Spica and reaches minimum brightness on the 24th, when it is only marginally brighter than the 1.0 magnitude star. Its elongation shrinks from about 80° to less than 60° during the month.

Jupiter and **Uranus** are at quadrature around the end of the month. Jupiter shows its greatest phase angle (or "least full" disk) in telescopes just a few hours after Venus. More important, magnitude −1.8 Jupiter is moving more swiftly east, pulling close to Beta Scorpii at month's end. Though dim Uranus resumes eastward motion on the 14th, it will complete the last of a trio of 1983 conjunctions with Jupiter next month.

The remaining planets, Mercury and Mars, are more difficult to see this month. **Mercury** is less than half a degree from Regulus on the evening of July 31 and also passes north of Venus in early August. But these conjunctions are not very good — even when Mercury is at a huge 27.4° greatest elongation on the 19th, it is almost impossible to glimpse the planet low in the west after sunset. The 1.9 magnitude Mars is only 24° from the Sun when it passes through the Beehive star cluster on the 24th and 25th, but its altitude in the morning sky is so good that

Aurorae have been called "spirits of the polar night," but the setting of Forrest Baldwin's photo — a cemetery — adds an eerie dimension to the phrase. Using 400 ASA film, Baldwin shot this picture in 3 seconds with a 50 mm lens set at f/1.4.

star dome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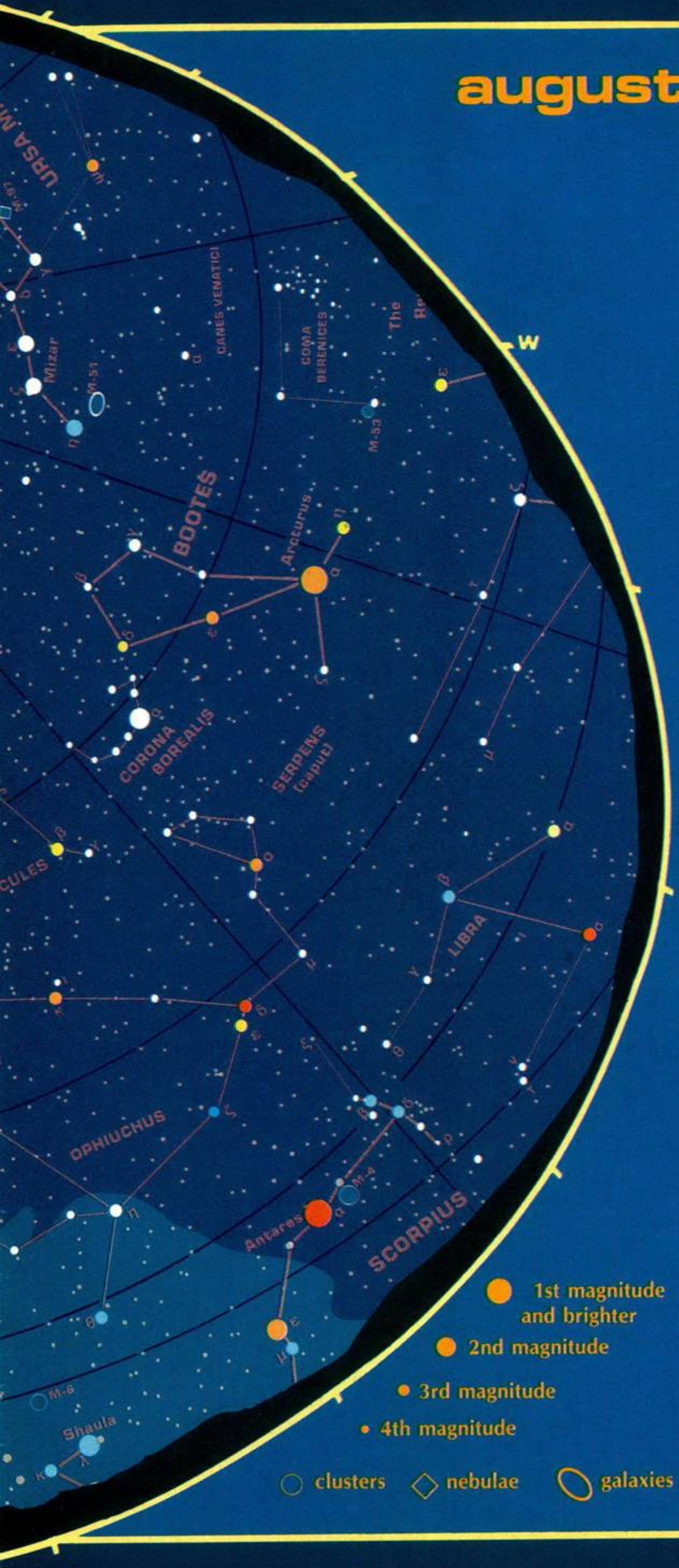
Vega
LYRA
M-57
Enif
M-15
EQUULEUS
M-27
VULPECULA
SAGITTA
DELPHINUS
AQUARIUS
Altair
AQUILA
CAPRICORNUS
MICROSCOPIUM
SERPENS (cauda)
M-11
SCUTUM
M-17
M-20
M-8
M-22
M-7
SAGITTARIUS
CORONA

The Star Dome shows how the sky looks at:

11:00 p.m. on August 1
10:00 p.m. on August 15
9:00 p.m. on August 31

august sky almanac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CORONA BOREALIS
SERPENS (Caput)
CULES
LIBRA
OPHIUCHUS
M-4
Antares
SCORPIUS
M-6
Shaula
1st magnitude and brighter
2nd magnitude
3rd magnitude
4th magnitude
clusters
nebulae
galaxies

1st Mercury will be close to Aldebaran (α Tauri) this evening. Though its separation from the Sun is moderately wide — and will become wider at greatest elongation on the 19th — the planet is at the beginning of the year's worst apparition and so is difficult to see. Last Quarter Moon occurs at 8:52 p.m. EDT.

8th New Moon is at 3:18 p.m. EDT; perigee occurs 12 minutes later (3:30) — 221,938 miles.

9th This evening, the Moon, Venus, and Mercury will all be grouped together in the western sky just after sunset.

11th Tonight and tomorrow night, be on the lookout for Perseid meteors (see text). The best viewing will be after midnight on both nights.

12th Venus is at aphelion; it is also very low in the western sky after sunset. How many more evenings can you keep it in view?

14th Asteroid Ceres is at opposition, magnitude 7.5.

15th First Quarter Moon occurs at 8:47 a.m. EDT.

16th The center of the Galaxy — shown by the crowded star-fields of Sagittarius — passes its highest elevation in the south around 8:30 local time tonight.

17th Mercury is at aphelion.

19th Mercury reaches greatest eastern elongation (27°), but it will be barely visible low in the western sky after sunset.

22nd The Moon is at apogee at 5:27 a.m. EDT — 252,448 miles.

23rd The Moon is Full at 10:59 a.m. EDT.

24th Venus passes through inferior conjunction. Start looking for it low in the eastern morning sky in about a week. Also, Mars will be passing the Beehive Cluster in Cancer (see text).

31st The Moon reaches Last Quarter at 7:22 a.m. EDT.

Joshua tree and crescent Moon make a twilight portrait in the Mojave Desert. A 10-second exposure, 400 ASA film, and 210 mm lens let J. Gibbons catch this picture.

it rises before the start of twilight — an event that should be interesting in binoculars.

Last but not least, there is the fine **Perseid meteor shower**. The Moon sets early on the big night, August 12-13. The shower is certainly worth some late-night viewing on many dates before and after this peak, but that particular night holds the few hours of enhanced peak activity that the shower has recently displayed. Rates of 50 to 60 per hour in clear, dark skies may be expected in the last few hours of the night, but if you are lucky enough to catch the enhanced peak, when the Perseid source point (called the *radiant*) is highest, a rate of 90 to 100 meteors per hour is possible for at least some observers. Try to note how many of the Perseids are bright, and also any interesting colors or other characteristics.

the starry sky

As twilight ends after a hot August day, relax in the cool air and enjoy one of the finest of sky-scenes. Besides this year's addition of Jupiter and Saturn (and for a while the vanishing Venus), you may see a few Perseids or, from the south, a few late Delta Aquarid meteors. And, as in every year, Arcturus will be sinking lower in the west, Capella and Fomalhaut starting to rise in the east. The heavens will be ruled — as always on August evenings — by the arching Milky Way and a brilliant blue star near the zenith.

Vega passes closer to the zenith than any other first-magnitude star for viewers near the well populated 40° north latitude circle. Marginally fainter than Arcturus, it is the brightest star of the traditional summer constellations and so really deserves the title a friend of mine once gave it: "the Sirius of Summer."

Though its spectrum is definitely bluer than that of Sirius, you can never make that comparison directly: the point opposite Vega on the celestial sphere is located right between Sirius and Canopus, another of the few stars brighter than Vega.

Vega is perhaps best known as the leading apex of the Summer Triangle, an asterism composed of three brilliant stars of three constellations. Vega itself is chief luminary of small **Lyra** the Lyre. Although it vastly outshines all else in the constellation, Vega is not the only interesting naked-eye object. The regular and rather short-period variable star **Beta** (*β*) **Lyrae** is another attraction. So, too, is **Epsilon** (*ε*) **Lyrae** — the famous "Double-Double" star in telescopes. To the average unaided eye it looks like an elongated point of light near Vega; sharp eyes can often split the odd point into two stars, as can the slightest optical aid. Can you separate the two stars on the very calmest nights of best "seeing"? Find out how often you can at least almost split this star without optical aid.

The other stars of the Summer Triangle are **Deneb** and **Altair**. Although Deneb is the faintest of the Triangle stars judging by apparent magnitude, it is really the brightest of the three, its light dimmed by great distance (1,600 light-years). In fact, Deneb is one of the most luminous stars in our local region of the Galaxy. Its name means "tail," indicating its position in the south-flying figure of **Cygnus** the Swan. The head or beak of this excellent constellation is the famous double star **Albireo** — but you'll need a good pair of steadily mounted binoculars to separate it into its lovely blue and gold components.

Altair is a 0.8 magnitude star (Vega is 0.0, Deneb 1.3) in **Aquila** the Eagle. At its distance of 16 light-years, Altair is the closest star after Sirius and Procyon. Aquila is not as prominent a constellation as Cygnus, but Altair and its two flanking stars form an asterism (sometimes called the Shaft of Altair) that is very noticeable indeed.

Whereas Lyra lies mostly outside its glow, Cygnus and Aquila are right in the midst of that luminous band known since ancient times as Via Lactea, the **Milky Way**. The part of the band we see in summer is the most prominent, including the star clouds of Cygnus, **Scutum**, and best of all, **Sagittarius**. When we look at the Large Sagittarius Star Cloud we are seeing the outlying stars of our Galaxy's hidden central glories.

In the region of Sagittarius are also various diffuse nebulae, including the Trifid, Omega (Horseshoe or Checkmark), Eagle (or Star Queen), and **Lagoon** Nebulae. The last of these, **M-8**, is visible even to the naked eye in dark skies.

Sagittarius is the Archer, but the most important stars of the constellation are often organized to form a Teapot (some of the same stars also are used to make a Milk Dipper). Diagonal from each other in the body of the Teapot are the two brightest stars of Sagittarius, second-magnitude **Kaus Australis** and **Nunki**.

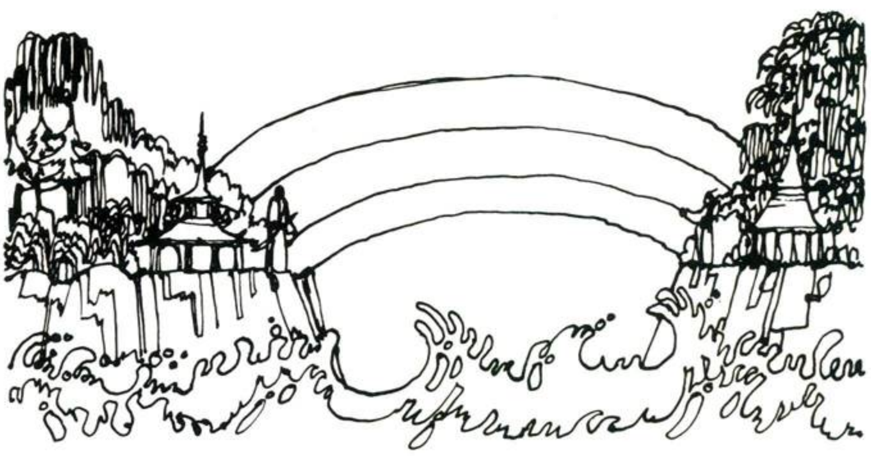
If you have binoculars, you can scan for all of the nebulae mentioned as well as a small spot just to the east of the star marking the Teapot's top — **M-22**, one of the brightest of all globular star clusters (visible to the naked eye in very dark skies).

And yet the naked-eye view of Sagittarius and this widest, brightest part of the Milky Way is unsurpassed. The star clouds here sometimes look like cumulus clouds lit by a distant city or by some mysterious glow in the starry night itself. In reality, they are self-luminous "clouds" of star after star, numerous as water droplets in a terrestrial cloud, but each a mighty sun. These star clouds are so vast, bright, distant, and enduring that all humanity's doings in the few thousand years of history are to them as physically insignificant as the briefest of passing rain showers on a long summer afternoon.

skylore

These days — when the Sun's flight across the sky is lower, but thunderstorms and summer showers are still common — are a good time for seeing rainbows. It would be difficult to praise the beauty and strangeness of the phenomenon too much. There are, of course, many legends about the rainbow — though few come close to conveying all of a sky-watcher's wonder.

A notable exception is the Biblical story of the role and origin of the rainbow — its first appearance was, of course, to Noah, when it formed to signify God's pledge never to again send the Flood. Because of the typical structure and movement of storms, the rainbow usually does follow rather than precede a storm, but this is not a hard and fast rule even in North America: "Rainbow in the morning (often on a storm coming from the west), sailors take warning."



In the midwestern U.S. I have seen the curious sight of lightning striking across the band of a rainbow. But the bow is usually associated with peace and (almost paradoxically) with otherworldly stirring. No wonder that Iris, goddess of the rainbow, was the Greeks' gentle messenger of the gods. (Her name, by the way, gives us the word "iris" for the colored part of the eye and "iridescent," an adjective meaning "rainbow-colored.")

Also familiar to many readers of mythology is the rainbow bridge from Midgard (Earth) to Asgard (the heavenly home of the Norse gods). This bridge was called Bifrost ("tremble-path"), and its colors were sometimes said to be reflections from the gems of which it was made. The Valkyries traveled across it to select worthy heroes from among those slain after battles.

The guardian of Bifrost was Heimdall, who was to sound his mighty horn when he saw the enemies of the gods approaching for the final battle that would end the world. When the infernal Surt and his multitudes of fire giants tried to ride their steeds across Bifrost, the rainbow bridge would catch fire and collapse beneath them. Only after the world-rending ruin of the battle would a few survivors (gods and mortals) come forth in a new world that would rise as a paradise from the wreck of the old flawed one.

Possibly another rainbow bridge is found at the beginning of Japanese myths, for it is said that the male and female divinities Izanagi and Izanami stood on Ama-no-uki-hashi, "Floating Bridge of Heaven," when they stirred the waters below with a jeweled spear to create the first island, Onogoro. It was on Onogoro that they settled and together begat many of the gods, creatures, and phenomena of the world.

The rainbow was highly venerated in both hemispheres. In Dahomey (Africa), the rainbow was thought to be the serpent Aido Hwedo, who was a servant of Thunder, but apparently also a transporter of the supreme creative being, the female spirit called Mawu (or Mahou or Mao). The excrement of this rainbow snake formed Earth's mountains.

In the New World, the Cherokees believed the rainbow was the tongue of the Celestial Serpent when he was drinking water. The Iroquois thought it was the wife of one of their most revered gods, Hino the Thunder Bird. A Sioux Indian named the epic poet John Neihardt "Flaming Rainbow," as the nearest Sioux equivalent of "poet."

Farther south in the New World, the Mayans called the rainbow Ix-chel, patroness of the art of medicine, a goddess who protected women in childbirth and sent life-giving rains. Still farther south, the Incas respected the rainbow as Cuycha, one of the attendants of the Sun and Moon.

Another people of South America thought the rainbow was a great and evil serpent. According to them, the serpent threatened the world, a monster slain by an array of almost all the world's birds. From their countless peckings flowed the monster's multi-colored blood to stain its arching corpse. Until then, all birds had been dark; now, they were stained ever after with the colorful blood of the rainbow — save for the few still-dark ones, who had not helped that day.

The narrative voice in one of Keats's poems says, "There was an awful rainbow once in heaven: / We know her woof, her texture; she is given / In the dull catalogue of common things. / Philosophy will clip an Angel's wings . . . " It seems likely that this, alone, was not the view of Keats himself. He probably recognized that greater scientific knowledge could also increase the sense of wonder.

From my own interest in the subject I know that there are wonders of the rainbow which only reading and study are likely to reveal. The enthusiastic sky-watcher will always identify with Wordsworth, who wrote of his own experience: "My heart leaps up when I behold / A rainbow in the sky."

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ANNOUNCEMENT — The Astronomical Society of Northwest Arkansas invites you to the third annual Alpena Starfest on August 6, 1983. Enjoy the dark skies of the northwest Arkansas Ozarks! For information send SASE to Alpena Starfest, c/o Don Banta, Rt. 8 Box 375, Harrison, AR 72601, or phone (501) 741-7511.

ANNOUNCEMENT — Observe the Perseid meteor shower with the Rockland Astronomy Club from the summit of Bear Mountain, about 35 miles north of New York City. Friday, August 12; if Friday is cloudy, Saturday, August 13. Contact the Rockland Astronomy Club, 204 N. Midland Ave., Nyack, NY 10960.

ANNOUNCEMENT — Tour the Milky Way with the Rockland Astronomy Club from the most beautiful vantage point in the New York metropolitan area, the summit of Bear Mountain. Friday, September 9; if Friday is cloudy, Saturday, September 10. For further information, contact the Rockland Astronomy Club, 204 N. Midland Ave., Nyack, NY 10960.

ANNOUNCEMENT — Large Schmidt-Cassegrain telescope available for use by a Boy Scout or Girl Scout troop, school, or other non-profit organization in the Danbury, Connecticut area. Contact Frederick Pauli, Jr., 29 Kingswood Rd., Danbury, CT 06810.

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ANNOUNCEMENT — The Northern Virginia Astronomy Club is holding the Burke Lake Telescope Meet on the weekend of August 5 and 6. For information and reservations, contact Richard Lawson, Secretary NOVAC, 5603 Flag Run Drive, Springfield, VA 22151.

WANTED — Information. Is there a club devoted to radio astronomy somewhere in the St. Petersburg, Florida area? Contact: WDX4U Monitors Station, 7401 5th Ave. North, Apt. 15, St. Petersburg, FL 33710.

WANTED — Small, private high school looking for a donation of a telescope for astronomy club. Receipts for full value of donations will be sent for tax purposes. We pay shipping. Contact PCHS Science Department, 625 Coleman, Los Angeles, CA 90042.

WANTED — Kokich cold camera in new or mint condition. Will pay reasonable price. Also information on cold camera techniques. Contact M. Chacon, 602 N. 12th St., Santa Paula, CA 93060.

WANTED — Meteor photographers for the Upsilon Pegasid meteor shower, which occurs just before the Perseids. Send SASE for free information sheet. Contact Florida Fireball Patrol, 215 Osage Dr., Indian Harbour Beach, FL 32937.

WANTED — Information or reports of mishaps involving Mylar/glass/pass solar filters (for Astronomical League safety report). Respondents need not be identified. Contact Frederick Pauli, Jr., 29 Kingswood Rd., Danbury, CT 06810.

WANTED — I am a 13-year-old amateur astronomer who needs help in finding deep-sky objects. I have a telescope that goes up to 400x. Any help would be greatly appreciated. Contact K. Ditto, 1423 Stewart Rd., Lincoln Park, MI 48146.

WANTED — Information on how I could take a degree in astronomy in any universities in the USA. Any advice or guidance from professional or amateur astronomers is welcome. Also, willing to buy any good quality reflector telescopes below US $200. Contact Jan Ju he, No. 62, Jlu. Harimau Bintang, Century Garden, Johor Bahru, Johor, Malaysia.

WANTED — *Space World* back issues: pre-February 1973, September/October 1973, July 1975, November 1975 to present. Also, materials on Apollo 1 (Grissom/White/Chaffee), such as press coverage, NASA releases, promos, etc. Contact Ken Gillies, 4810 42A Avenue, Delta, British Columbia, Canada V4K 1A1.

WANTED — I would appreciate hearing from anyone owning a Schmidt-Cassegrain telescope, preferably a Celestron or Meade; also information from anyone owning an Odyssey 1 or 2 Dobsonian. I need the information to find out any problems with these telescopes before I decide to buy one. Contact Chris Genge, 332 Deer Park Dr., Roches Point, Ontario, Canada L0E 1P0.

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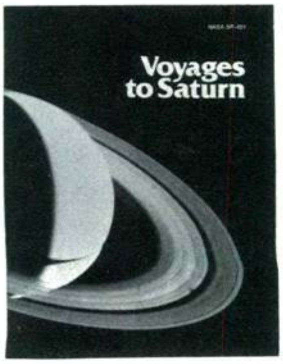

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WANTED — Polaroid astro camera. Contact Jim Morris, 2026 Johnson Dr., Sioux Falls, SD 57105.

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WANTED — Any and all usable astronomical equipment and materials for use in small high school astronomy program. Anticipated start of program is September. Donations acknowledged on letterhead. For further information contact Tony Heinzman, Bear Valley Astronomical Society, 1071 Mountain Lane, Big Bear City, CA 92314. Phone (714) 585-5486.

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gazer's gazette

the 50 finest double stars for a 60mm refractor

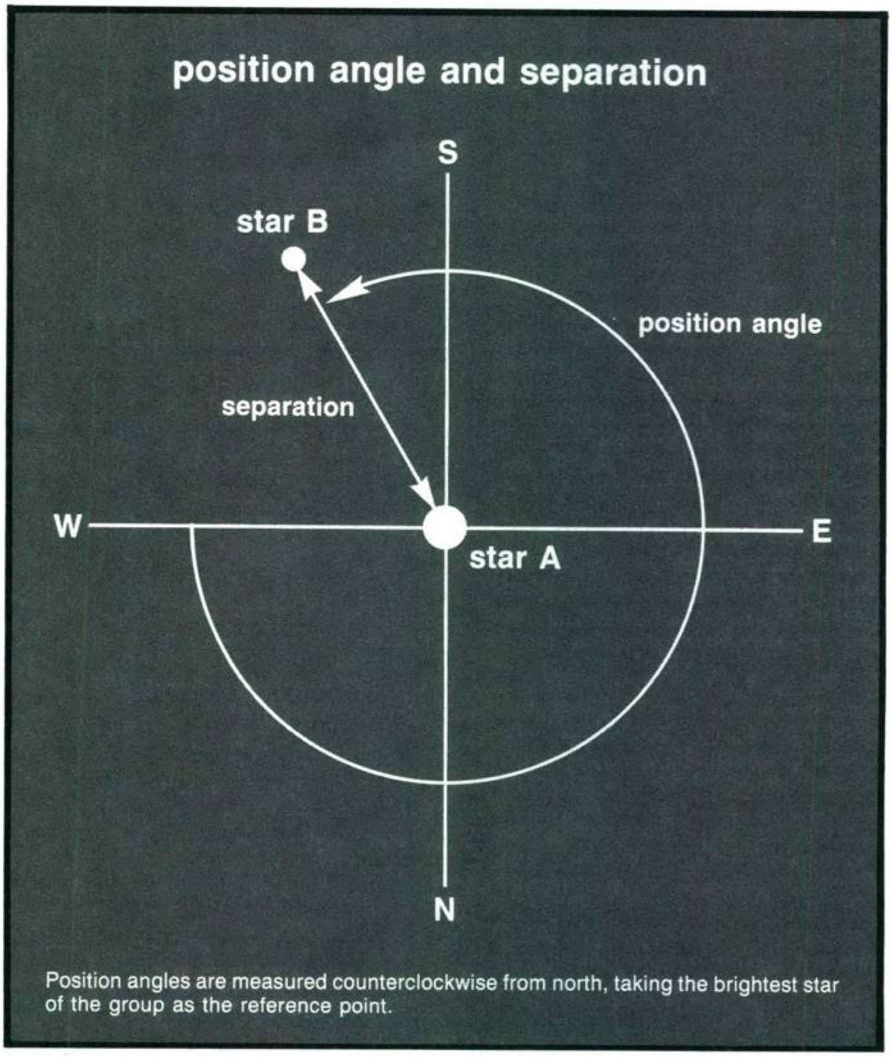
by
Robert A. Freeman

Double stars have fascinated astronomers ever since Giovanni Battista Riccioli discovered the first telescopic pair, Zeta (ζ) Ursae Majoris (better known as Mizar) in 1650. Six years later, Christiaan Huygens found Theta (θ) Orionis, the Trapezium quadruple star in the Orion Nebula. Robert Hooke added Gamma (γ) Arietis in 1664. The first Southern Hemisphere doubles, Alpha (α) Crucis and Alpha Centauri, were found by J. de Fontenoy in the late 1600s. In the first half of the 18th century, Gamma Virginis, Castor, and 61 Cygni were all found to be double by James Bradley and James Pound.

But it was not until 1767 that the idea was first advanced that double stars might be physically related objects and not just chance visual alignments. By the early 1800s, the observations of Sir William Herschel and others had confirmed that many stars that appear double are, in fact, actual stellar systems revolving around common centers of mass under the guidance of Newton's laws of motion. Since then, more than 64,000 double and multiple stars have been cataloged.

Double stars are well suited to today's backyard observing. Despite the strong recent emphasis on big scopes with sophisticated accessories, the most common instrument around is probably still the 60mm refractor — the old "two-point-four." The hoopla over large aperture Newtonians tends to create an impression that observers with more limited equipment have been left in the cold with nothing to see. Yet from even the most light-polluted urban site, a modest 60mm telescope can reach out and take you into a fascinating world — that of double star astronomy.

The table on pages 51 and 54 lists 50 double and multiple star systems — my pick of the "best and brightest." These are the winners that emerged from a great many observations made with an equatorially mounted 60mm refractor. They require nothing special in the way of observing skills. Most of the time, I used a 9mm orthoscopic eyepiece, which yielded a magnification of 100x in a field about 0.4° across. Nor are these doubles dim and close: theoretically, a 60mm scope has a limiting magnitude of about 12.4, and its resolution limit is about 1.9" of arc. In practice, however, I found these limits were unrealistically generous — atmospheric conditions and other limitations usually kept the magnitude limit to 10 or only a little fainter. (While I could momentarily glimpse fainter stars using averted vision, the images weren't good enough to be seen clearly.) Likewise, to get a clean split on pairs having nearly equal brightnesses, I found the practical lower limit for separation was about 2.3" of arc, instead of the 1.9" theoretically possible. Stars whose components differed by several magnitudes forced a minimum



Position angles are measured counterclockwise from north, taking the brightest star of the group as the reference point.

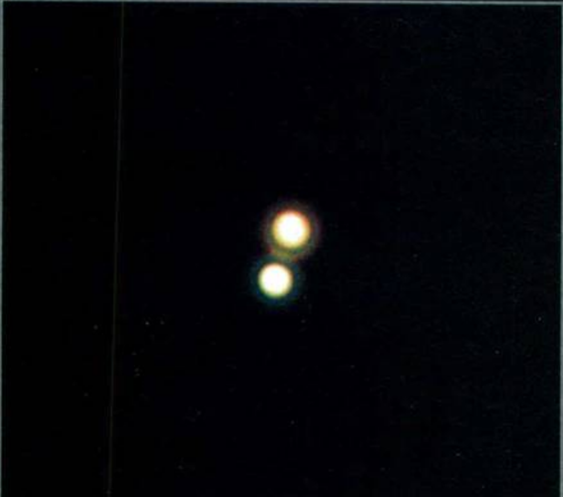
the fifty finest double stars for 60mm refractors

star	r.a. (2000) dec.				magnitude		p.a.	sep.	comments
	hr	min	°	′	a	b,etc.		″	
Eta (η) Cas	00	40	57	49	3.5	7.2	307°	12	great contrast in brightness, white and uncertain, very nice double
Psi¹ (ψ¹) Psc	01	06	21	30	4.9	5.0	160°	30	yellow and yellowish white, nice separation, equal brightness
Zeta (ζ) Psc	01	14	07	35	4.2	5.3	63°	24	yellowish and orangish, color contrast and separation both very nice, both may be variables
Gamma (γ) And	02	04	42	21	2.3	5.1	63°	10	brilliant pair, very yellowish and bluish, appear closer, great brightness difference
Σ331 Per	03	01	52	51	5.5	6.5	86°	12	gold and orangish, color contrast slight, nice pair
32 Eri	03	54	-02	57	5.0	6.0	345°	6.9	nice pair, gold and greenish blue, good contrasts
1 Cam	04	32	53	54	5.0	6.0	308°	10	white and bluish, pretty pair at nice separation
118 Tau	05	29	25	10	6.0	6.5	206°	5.1	white and red, close, interesting pair
Delta (δ) Ori	05	32	-00	18	2.2	6.7	360°	53	bright, yellowish white and reddish, beautiful, secondary seems brighter
Lambda (λ) Ori	05	35	09	56	4.0	6.0	44°	4.4	striking, white and orangish, difference in brightness seems greater
Theta¹ (θ¹) Ori	05	35	-05	22	5.4	6.3 v(6.7-7.7) v(8.0-8.7)	 61° 311°	9.0 13 13 (c-d)	four component trapezium, incredible, beautiful multicolored foursome
Theta² (θ²) Ori	05	37	-05	25	5.2	6.5	92°	53	wide white pair in overwhelming field
Iota (ι) Ori	05	36	-05	53	2.8	6.9	141°	11.4	gemlike dazzling primary in excellent field, white and blue
Sigma (σ) Ori	05	39	-02	37	3.9	6.5 7.5	61° 84°	42 13	fantastic field, beautiful orangish, blue and white, super triple
Gamma (γ) Lep	05	45	-22	25	3.6	6.2	351°	95	yellowish and faint blue, nice field, wide but seem closer
Beta (β) Mon	06	29	-07	02	5.0	5.5 6.0	132° 107°	7.4 2.8 (b-c)	stunning triple, one pair very close, colorful, all yellowish with tints
12 Lyn	06	46	59	27	5.5	7.5 6.1	308° 259°	8.5 1.7	fine colors, seem brighter, bluish white and orangish red
Alpha (α) Gem	07	35	31	54	2.0	2.8	88°	2.7	brilliant blue-white and yellowish "peanut" shaped, separation almost complete
k Pup	07	39	-26	47	4.5	4.5	318°	9.8	dazzling near equal whites
Iota (ι) Cnc	08	47	28	46	4.5	6.5	307°	31	wide contrasty yellow and blue, nice
Gamma (γ) Leo	10	20	19	51	2.5	3.5	122°	4.4	blazing, close unequal white duo
54 Leo	10	56	24	45	4.5	6.5	110°	6.5	unequal white, unimpressive
Xi (ξ) UMa	11	18	31	32	4.5	5.0	105°	2.9	white and yellowish white, almost touching
N Hya	11	32	-29	15	6.0	6.0	210°	9.0	yellowish equal, nice color and separation
24 Com	12	35	18	22	5.2	6.7	271°	20	orangish and whitish, nice color contrast
Gamma (γ) Vir	12	42	-01	28	3.5	3.5	293°	3.6	white and yellowish, equal brightness, noticeable color difference
Alpha (α) CVn	12	56	38	19	2.9	5.6	228°	20	beautiful, wide, very bright, white and pale orange
Zeta (ζ) UMa	13	24	54	55	2.4	4.0	150°	14	white and greenish or yellowish white, beautiful
Pi (π) Boo	14	41	16	25	4.9	5.8	108°	5.6	blue and orange, very nice
Xi (ξ) Boo	14	51	19	07	4.7	6.8	332°	7.2	white and yellow, very nice
Delta (δ) Ser	15	35	10	32	4.2	5.2	178°	3.9	beautiful blue and orange, appears wider
Beta (β) Sco	16	05	-19	48	2.6	4.9	22°	14	very fine, white and orange, good color contrast
Sigma (σ) CrB	16	15	33	51	5.5	6.0	233°	6.2	white and orange, difference in brightness seems greater

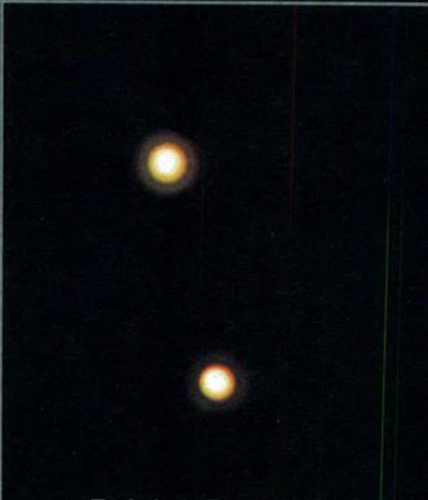
list continued on page 54

seeing doubles with a 60mm refractor

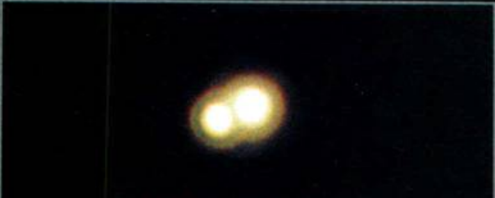
Epsilon^{1,2} ($\varepsilon^{1,2}$) Lyrae



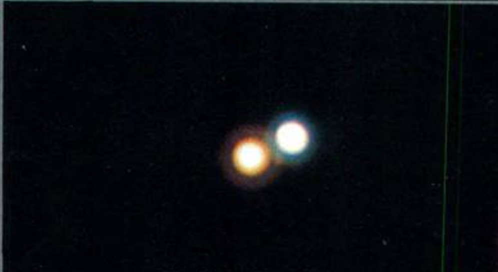
32 Eridani



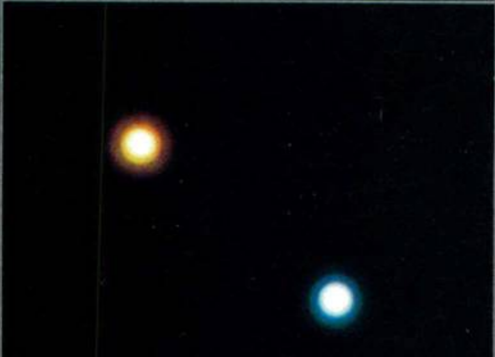
Psi (ψ) Draconis



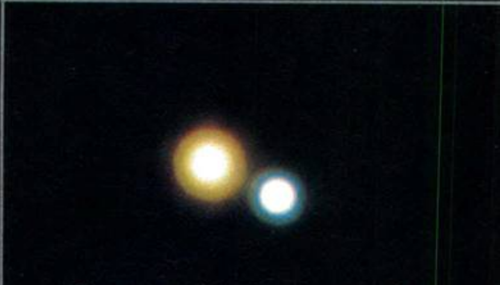
Alpha (α) Herculis



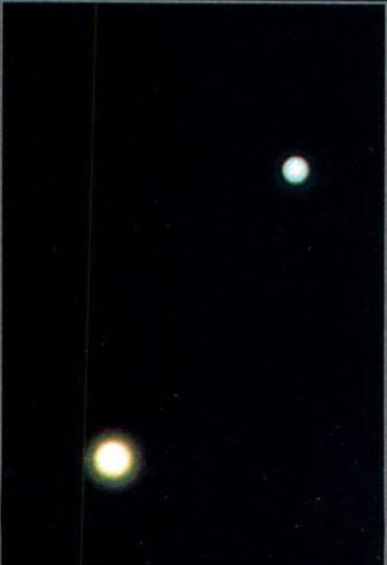
Pi (π) Bootis



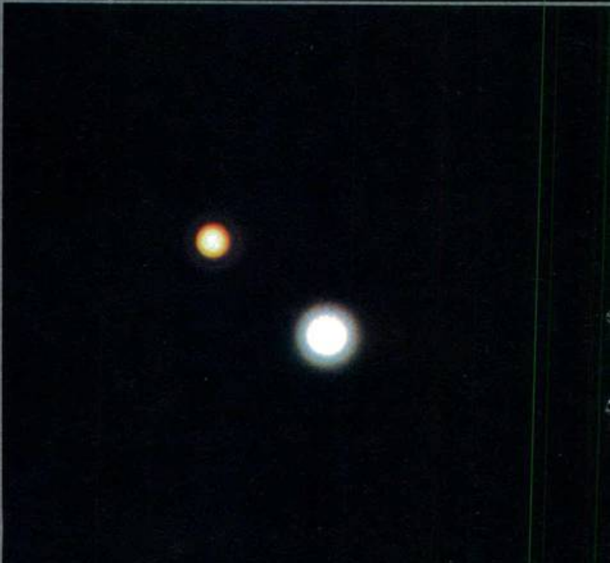
Beta (β) Cygni



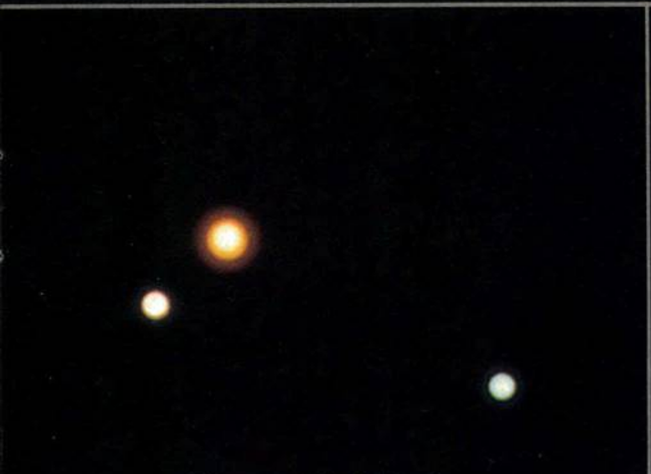
Gamma (γ) Andromedae



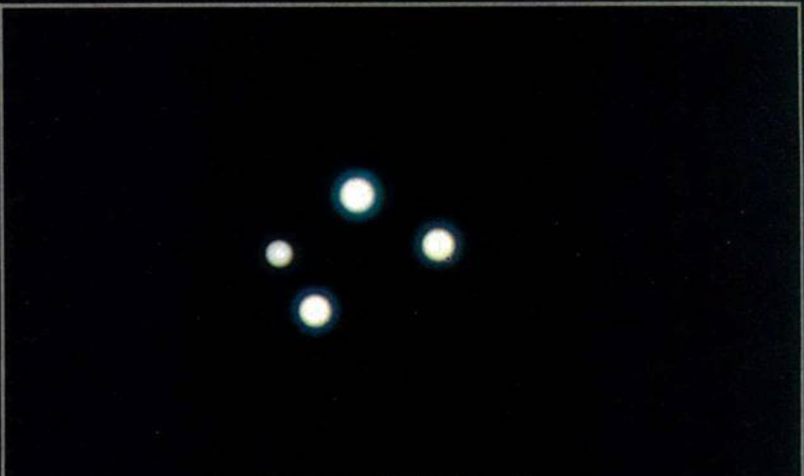
Beta (β) Lyrae



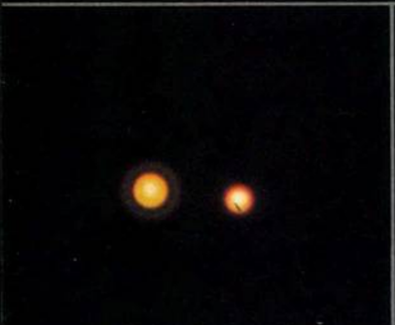
Alpha (α) Canum Venaticorum



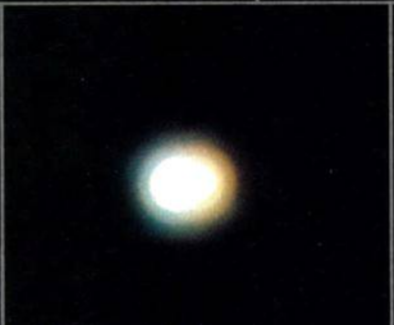
Sigma (σ) Orionis



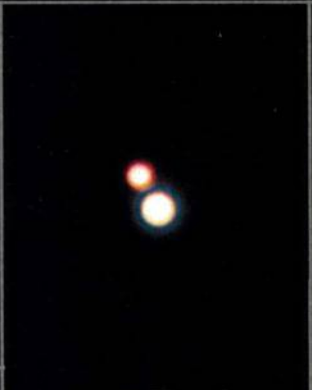
Theta^{1} (θ^{1}) Orionis



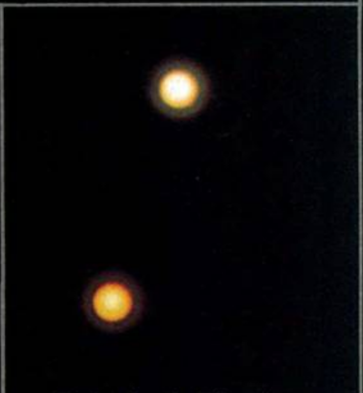
Σ331 Persei



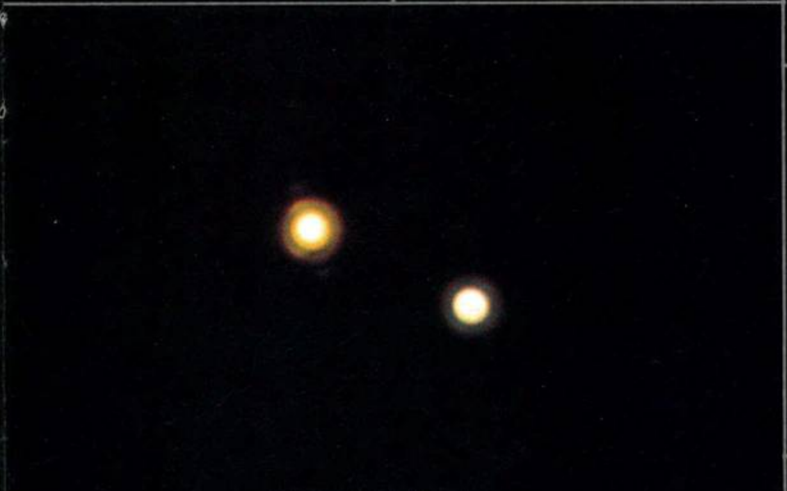
Alpha (α) Geminorum



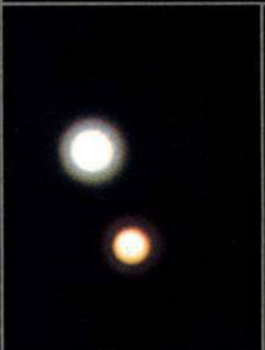
118 Tauri



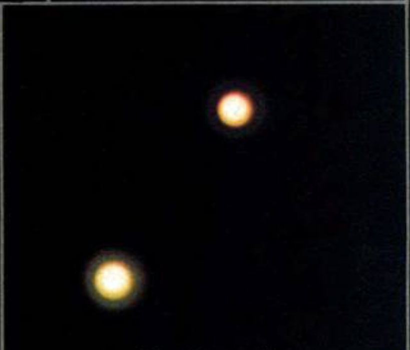
Psi^{1} (ψ^{1}) Piscium



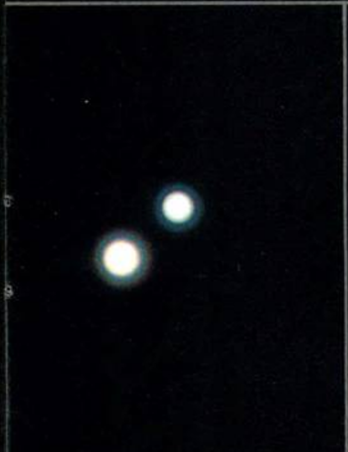
Zeta (ζ) Piscium



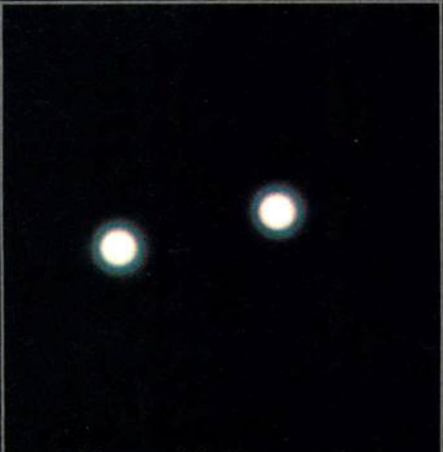
Beta (β) Scorpii



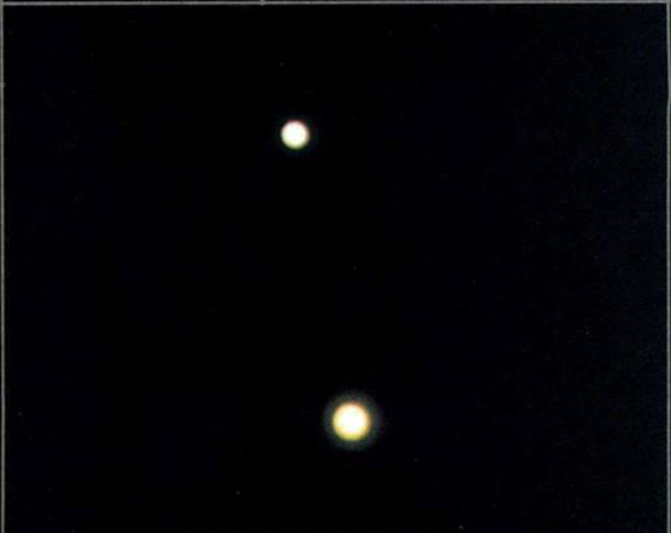
61 Cygni



1 Camelopardalis



Theta (θ) Serpentis



Delta (δ) Cephei

Special effects photography by Ken Novak, Communigraphics

finest double stars for 60mm refractors

16+17 Dra	16	36	52	54	5.0	5.6 6.6	194° 109°	90 3.2 (b-c)	fine triple, all white in excellent field, close and wide combination
Mu (μ) Dra	17	05	54	28	5.8	5.8	42°	2.0	yellowish orange and bluish white, very colorful, very close, almost touching
Alpha (α) Her	17	15	14	24	3.0	5.4	107°	4.6	yellow and yellowish white, pale secondary
36 Oph	17	15	-26	33	5.5	5.5	154°	4.4	yellowish white and orangish white, good separation for this brightness
Psi (ψ) Dra	17	42	72	10	4.9	6.1	15°	30	yellow and orangish yellow, nice separation and brightness
40+41 Dra	18	00	80	01	5.5	6.0	232°	19	white and off-white, slight brightness difference, nice pair in nice field, another star 120″ distant
95 Her	18	02	21	36	5.1	5.2	258°	6.3	very near equal brightness, yellowish to orangish
Epsilon^1 (ε^1) Lyr Epsilon^2 (ε^2)	18	44	39	40	5.4 5.1	6.5 5.3	358° 92°	2.7,2.3 208″ between pairs	all white, closer pair difficult split
Zeta (ζ) Lyr	18	45	37	36	4.3	5.5	150°	44	greenish white and orangish white, bright and very wide
Beta (β) Lyr	18	50	33	21	v(3.4-4.3)	7.0	149°	47	off white and blue, very pretty with wide separation and large brightness difference
Σ2404 Aql	18	51	10	58	5.7	7.0	183°	3.5	colors marked, orange and reddish, close pair
Theta (θ) Ser	18	56	04	12	4.6	5.0	103°	22	fine white pair, seem brighter
19 Lyn	19	23	55	18	5.5	6.5	315°	15	bluish white and orangish, contrasting colors with good separation
Beta (β) Cyg	19	31	27	57	3.1	5.1	54°	34	superb brightness and color, gold and blue
Gamma (γ) Del	20	47	16	08	4.3	5.1	268°	10	magnificent yellow pair with slightly different tints
61 Cyg	21	06	38	41	5.3	5.9	146°	28	yellowish and reddish, a little wide for this brightness
Σ2816 Cep	21	39	57	30	6.3	7.9 8.0	121° 339°	12 20	fantastic, beautiful triple, though slightly dim
Delta (δ) Cep	22	39	58	26	v(3.9-5.1)	6.3	192°	41	beautiful colors, yellow and blue, very nice

separation two or three times wider still.

Concerning star colors — a notoriously controversial topic — my observations tend to bear out the comment of the famed observer F.G.W. Struve that, among doubles, pairs with components of similar brightness usually exhibit similar colors. And the probability of color contrast is proportional to the difference in brightness, with fainter stars usually appearing bluer. I've seen this myself, and suspect that anyone observing doubles for long will also notice it — as well as a kind of separation-brightness factor that seems to accentuate how the contrasts in color are perceived.

You should keep in mind that double and multiple stars are *not* static. Many exhibit orbital motions that gradually affect the visual separation of the components. Although the great majority of these motions are extremely slow, requiring decades or centuries for significant movements, some systems may close down to become unresolvable in the near future — while others, too close to be resolved now, will open up in the years to come. Many of the systems on the list contain additional visual and spectroscopic components beyond the reach of 60mm refractors. I omitted these for simplicity's sake.

In compiling the list, I wound up picking star systems whose components were magnitude 8.0 or brighter and had separations between 2.0″ and 100″. The stars also lie north of -30° declination — I live at 42° north latitude and felt it proper to leave out some fine southerly pairs that can only be observed when they're low in the sky. In all, some 32 constellations out of 88 are represented; Orion leads the list with five first-rate doubles. Five of the 50 systems have more than two visual components within the grasp of a 60mm refractor. The brightest are Alpha Geminorum, Delta Orionis, Zeta Ursae Majoris, and Gamma Andromedae; the faintest are the beautiful triple Σ2816 in Cepheus and 118 Tauri.

You'll find that some of these systems lie in parts of the sky where the celestial guideposts are few. Observers without accurate setting circles on their scopes will require a good star chart and finderscope to locate some of them. All the stars on the list are plotted in the old Skalnate Pleso *Atlas of the Heavens* and on Tirion's *Sky Atlas 2000.0.* Many of the brighter objects are on the charts in *Norton's Star Atlas* as well.

I hope you don't come away with the idea that the list is some kind of test of how good an observer you are or what the maximum performance of your instrument is! Rather, it's a collection of the most pleasing stellar compositions I've found. Anyone who looks at all 50 is guaranteed a satisfying journey through the heavens. You'll come away with an increased interest in double stars as well a new appreciation for the capabilities of your telescope, however modest.

Robert A. Freeman is an amateur astronomer with over 20 years of observing experience. He is an avid AAVSO member.

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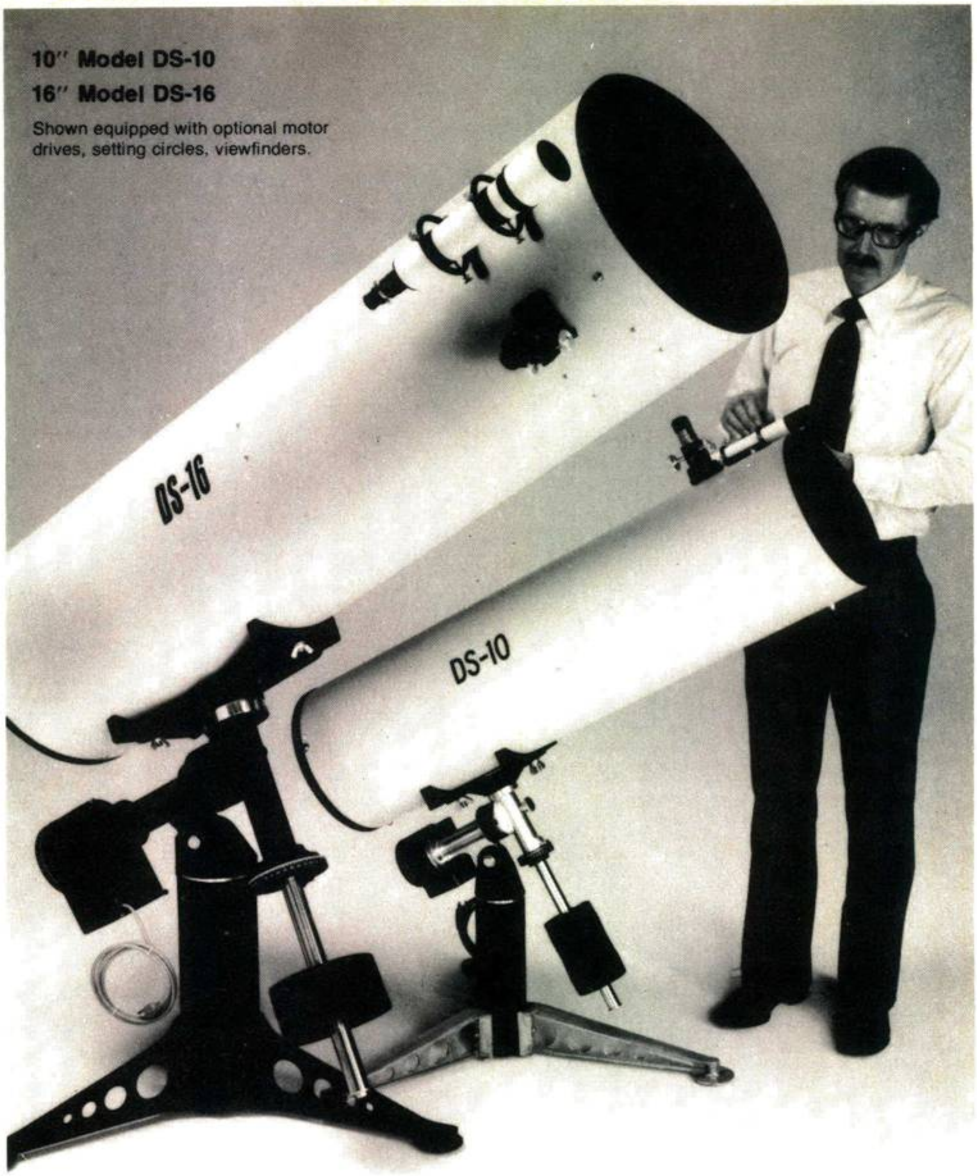


10″ Model DS-10
16″ Model DS-16

Shown equipped with optional motor drives, setting circles, viewfinders.

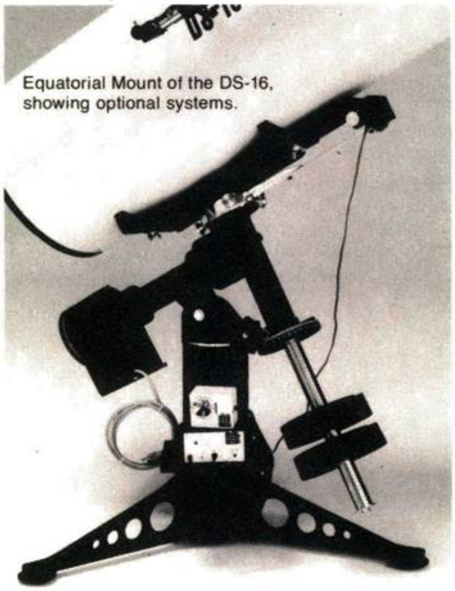
Ever expect to see the Great Nebula in Orion (M42) as a glowing blue-green ember? Or resolve the Hercules globular cluster (M13) to the core? Or observe the dust lanes and spiral structure in the Whirlpool Galaxy (M51)? Not just photographically, but **visually**. Now you can, and can afford to, observe these and countless hundreds of other objects as you've never seen them before. The incredible Meade DS-16, with **50%** more light-gathering area than other 13″ telescopes, has just opened up a new universe for you.

Consider the possibilities in astrophotography: Capture the glowing yellow-red detail of the Ring Nebula (M57), including the 15th-magnitude central star, in **4 minutes;** or the complete red, blue and green structure of the Orion Nebula, including the diffuse outer loop in **6 minutes;** the fiery-red gaseous detail of the Omega Nebula (M17) in **5 minutes;** the dust lanes and spiral detail of the Andromeda Galaxy (M31) in **5 minutes or less!** Exposure times so short you really don't need a drive corrector or guide telescope— so short that even a beginner can obtain astrophotos of exquisite detail.

Manufactured exclusively for Crown Optics by Meade Instruments Corp., the World's largest manufacturer of reflecting telescopes for the serious amateur, the DS-10 and DS-16 make available to the average amateur visual and photographic capabilities only dreamed of until now. Unlike competing large-aperture telescopes, the Meade DS-Series Telescopes include **Equatorial Mounts** as standard equipment: you track effortlessly along **one** axis, not along 2 simultaneous axes as with an alt-azimuth mounting. Add the optional Electric Motor Drive System and you're ready for fully automatic tracking and the deep-space photography you never thought possible.

SPECIFICATIONS— Meade DS-10: 10″ f/4.5 Reflecting Telescope. With null-figured, diffraction-limited Pyrex parabolic primary mirror and matching (2.60″ M.A.) 1/10-wave flat elliptical secondary; #67 rack-and-pinion focuser at convenient observing position; Kellner 25mm (46×) eyepiece; Sonotube 12″ I.D. × 46″ long, sealed and attractively Zolatone coated; all-metal, precision-machined Equatorial Mount, with ultrasmooth nylon bearings and 1″ solid steel shafts; rock-solid, low-profile pier and tripod legs; locks on both axes. Complete: **$449.50**.

SPECIFICATIONS— Meade DS-16: 16″ f/4.5 Reflecting Telescope. With null-figured, diffraction-limited, Pyrex parabolic primary mirror and matching (4.00″ M.A.) 1/10-wave flat elliptical secondary; flotation mirror cell; #67 rack-and-pinion focuser at convenient observing position; Kellner 25mm (73×) eyepiece; Sonotube 18″ I.D. × 68″ long, sealed and attractively Zolatone coated; all-metal, precision-machined Equatorial Mount, with ultrasmooth Nylon bearings, 1½″ solid steel shafts, and 5″-dia. polar thrust surface; rock-solid, low-profile pier and tripod legs; locks on both axes. Complete **$1185.00**.



Equatorial Mount of the DS-16, showing optional systems.

OPTIONAL SYSTEMS

#787	**Electric Motor Drive System (115v./60Hz) for DS-10 ....**	**$ 60.00 ppd.**
#897	**Electric Motor Worm-Gear Drive System (115v./60Hz) for DS-16 ....**	**155.00 ppd.**

See our ad on the next page for the wide array of other optional accessories for the DS-10 and DS-16. These include: higher- and lower-power eyepieces; viewfinders; telenegative amplifiers; nebular filters; drive correctors and photoguide telescopes for long-exposure photography; camera adapters. The *giant Meade* #680 Focuser may also be ordered in place of the standard focuser on the DS-10 and DS-16. See Bulletin DS for details.

- Both models are **complete** instruments at the prices listed— no additional parts or accessories required to start observing.
- Easy Portability— Field set-up time is about 2 minutes for the DS-10, 5 minutes for the DS-16.
- The DS-10 and DS-16 carry the Meade Full-Year Limited Warranty.
- **Prompt shipment** on both models— Order by mail, or by dialing the Crown TOLL-FREE 800-number. (See next page for details.)
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1— **Model 300PG**: D=80mm (3.1"); F=1200mm (f/15) **$185.00 ppd.**
2— **Model 280PG**: D=60mm (2.4"); F=700mm (f/11.7) **79.50 ppd.**
3— **Model 210PG**: D=50mm (2.0"); F=600mm (f/12) **57.50 ppd.**
Mounting Rings: for #210PG .... per. pr. **9.75 ppd.**
for #280PG, #300PG ..... per. pr. **12.50 ppd.**

RACK-AND-PINION FOCUSERS— All 3 models include helical-cut rack and variable-tension adjustment for ultra-smooth focusing without backlash. Universal bases fit all tube sizes. Standard 1¼" eyepiece holders.

4— **Model 67** — Strong, lightweight design for 4" to 10" telescopes. 2-3/16" travel. An excellent value. **$23.50 ppd.**
5— **Model 640** — A heavy-duty deluxe focuser for 6" to 16" telescopes. Full 3" travel for both visual and photographic applications. **$36.95 ppd.**
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ACCESSORY CASES— For secure storage of eyepieces, Barlows, filters.

7— **Model 54**: Thick-wall polyethylene with latch and handle. Holds 7 eyepieces & Barlow, filters. Dims. 12" × 8" × 3¾" **$12.50 ppd.**
8— **Model 50**: Luggage-quality metal case with 2 latches, handle; foam custom fits to your accessories.
Dims. 20" × 12" × 6½" .... **$39.50 ppd.**

NEBULAR FILTERS—Revolutionary 3-channel filters block natural airglow & sodium and mercury emissions from city lights. Dramatically improve telescope performance visually and photographically.

9— **Model 907**: 18mm aperture, for .965" O.D. eyepieces **$42.50 ppd.**
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12—**PHOTO-VISUAL COLOR FILTERS**—Top quality optical glass, dyed-in-the-mass, with excellent spectral homogeneity. Thread directly into 1¼" O.D. barrels. Filters may be piggybacked. **#8 Light Yellow—#11 Yellow-Green—#12 Yellow—#21 Orange—#23A Light Red—#25A Red—#47 Violet—#58 Green—#80A Blue—Polarizer (30% transmission).** Each filter: **$7.50 ppd.** Set of any 6: **$43.50 ppd.**—Full set of 10: **$70.00 ppd.**

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14—**VARIGUIDE DRIVE CORRECTOR— Model 41**: The finest R.A. drive corrector available. Includes aircraft-type joystick controller for continuously variable correction rates. Variable speed control. Use with any telescope drive rated up to 12 watts. Operates from 12 v. D.C. or 115 v. A.C. **$110.00 ppd.**

15—**6 × 30mm VIEWFINDER—Model 631**: Same unit supplied as standard equipment on Meade 6" and 8" reflecting telescopes. Actual field: 4°. Includes coated, achromatic objective lens and crosshair eyepiece. Precise push-pull focusing. Thousands now in use. Bracket, with collimation screws and lock-nuts, included. Bracket fits all tubes 6" to 12½". **$24.50 ppd.**

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17—**SERIES 1 KELLNER EYEPIECES (1¼" O.D.)**—High-quality, fully-coated optics housed in chromed barrels threaded for filters. Sold elsewhere for $18.00 to $22.00. **KE 9, 25, 40mm** .... each **14.75 ppd.**

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19— **SERIES 2 MODIFIED ACHROMATIC EYEPIECES (1¼"O.D.; MULTI-COATED)**—Custom 3-element designs, precisely corrected for chromatic and spherical aberrations. Finest obtainable under $20.
FOCAL LENGTHS: MA 6,9,12,25mm, 40mm Wide-Field, ea. $18.95 ppd.

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28—**RESEARCH-GRADE ERFLE 32mm EYEPIECE (2" O.D.; MULTI-COATED)**—Wide-angle, fully-corrected 65° field. The finest eyepiece obtainable in 2" barrel. **$99.50 ppd.** Adapter Barrel for 1¼" O.D. **$10.75 ppd.**

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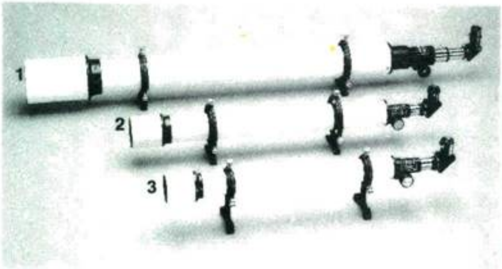

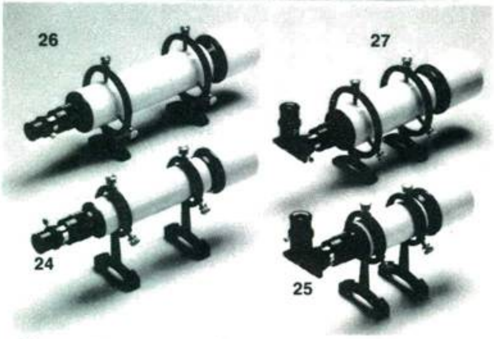

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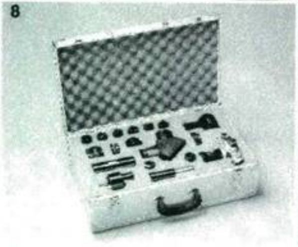

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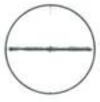

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8″ Schmidt-Cassegrain

Meade Model 2120
10″ Schmidt-Cassegrain

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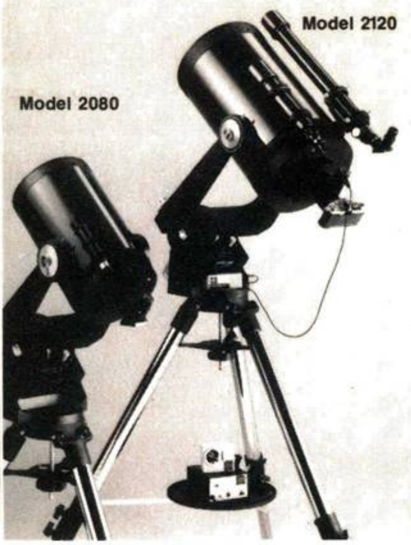

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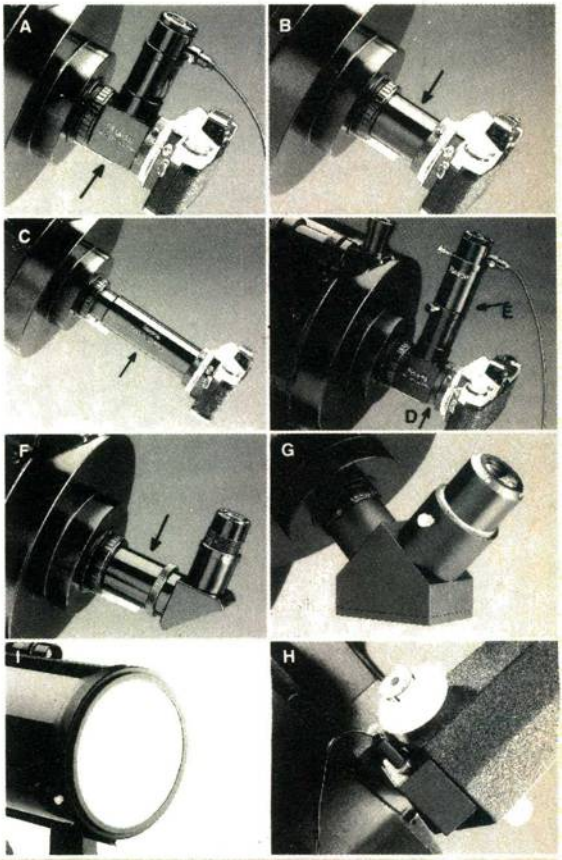

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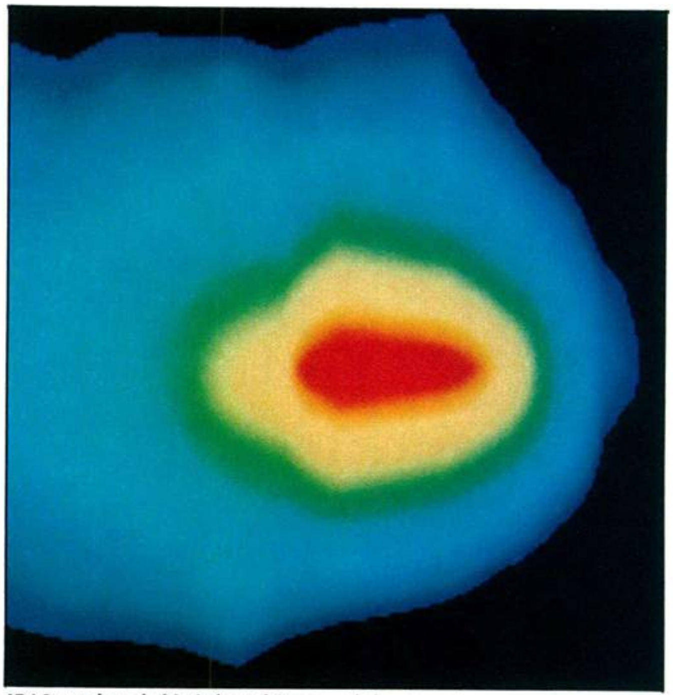
ASTRO NEWS

Scientists Assault a Comet



IRAS produced this infrared image of the comet.

Comet IRAS-Araki-Alock burst on the astronomical world very suddenly — a small comet moving on an orbit that would take it, in a matter of days, halfway across the sky and within three million miles of Earth.

The discovery story began during routine scans across the sky on April 26, as the Infrared Astronomical Satellite's field of view swept across the constellation Cygnus. On two successive orbits, the satellite's infrared telescope detected a bright infrared source that appeared to have moved in the 100-minute interval between the scans. Although the prime mission of IRAS is to detect "fixed" objects — stars and galaxies — John Davies and Simon Green of Leicester University (UK), and Brian Stewart of the Rutherford Appleton Laboratory (UK), using specially developed software at the IRAS Preliminary Analysis Facility, recognized the object as a fast-moving solar system object.

From the infrared data, Davies and Dr. H. Aumann of the IRAS Science Team deduced the object's temperature — a temperature high enough to place it in the inner solar system. Since the IRAS positions showed the object was well above the plane in which the planets orbit the Sun, the object was clearly a new and unusual object, worthy of further study.

Within hours of its detection on April 26, the IRAS scientists sent telegrams to a network of observatories around the world — a special network organized by Leicester University for just such an eventuality. The next day, Swedish astronomer T. Oja of Kvistaberg obtained photographic plates showing a comet-like object with a central condensation 15 to 20 seconds of arc in diameter. These observations were telegraphed to the IRAS Control Centre at the Rutherford Appleton Laboratory and then passed, together with data from the original IRAS detection, to the Smithsonian Astrophysical Observatory.

The SAO's Central Bureau for Astronomical Telegrams announced the discovery as Comet IRAS-Araki-Alcock in its Circular No. 3796, dated May 4. It reported that J. Gibson took plates of the IRAS object at Palomar Mountain on May 2.5, but that "before he could inspect these plates," George Alcock of Peterborough, England, reported he had discovered "a possible bright comet" on May 3, and that "within an hour confirmation of the discovery was received" from G. Hurst of Wellingborough, England. Suspecting that the two comets were identical, the Bureau obtained the IRAS information from Gibson at Palomar, who had by then found the comet on his plates. Gibson's plates showed a strongly condensed nucleus with a weak, asymmetric coma some two arc-minutes across, brighter on the northeastern side, with no evidence of a tail. In the meantime, Y. Kozai of Tokyo Observatory telexed the Bureau that Genichi Araki had independently discovered the seventh-magnitude comet on May 3, about seven hours before Alcock.

The next circular, No. 3797, contained a preliminary ephemeris for the comet showing that it would pass closest to Earth on May 11 and possibly become as bright as magnitude 2. The orbit was assumed to be parabolic (usually a good assumption for an unknown comet), with a perihelion distance of 0.9913 AU and an inclination to the ecliptic of some 73°.

Visual and photographic observations began to pour in from around the world. Optical astronomers quickly bargained for a few hours of big telescope time from colleagues and obtained the first spectra of IRAS-Araki-Alcock, showing the spectrum of the nucleus to be reflected sunlight, but detecting faint C_2 molecular emissions from the coma. In addition, short-exposure plates to obtain vitally needed accurate positions were taken and reported; a more accurate ephemeris was issued based on observations made up to May 6, but the estimated errors in the predicted positions were still large — possibly as large as five minutes of arc.

Meanwhile, radio and radar astronomers hurried to observe the comet while it was still nearby. According to Don Campbell, director of Arecibo Observatory, IRAS-Araki-Alcock passed through the radio telescope's entire area of coverage in one day. "There was quite a lot of running around. We only had one shot at it due to errors in the ephemeris, but a good strong signal." Radar beams were bounced off two other comets, Encke and Grigg-Skjellerup, both 0.3 AU from Earth. The new comet was only 0.03 AU distant when Arecibo detected it in the S-band (13-centimeter wavelength). If the comet's nucleus is similar in size to the others detected by Arecibo, the signal it returned was some 10,000 times stronger. Preliminary analysis of the return signal suggests that the nucleus is about one kilometer in diameter.

Ultraviolet astronomers responded also, swinging the International Ultraviolet Explorer satellite toward the comet. They reported clear emissions due to hydrogen (Lyman-alpha), sulfur, the CS molecule, ionized carbon dioxide, and the OH molecule. Michael A'Hearn, from the University of Maryland, reported preliminary determination that the comet was producing roughly 9×10^{27} OH molecules per second and 5×10^{25} CN molecules per second, as part of a program to search for H_2O and HCN in the radio spectrum of the comet.

Meanwhile, in Goldstone, California, the 64-meter dish of NASA's Deep Space Network bounced S-band and X-band (3.5-centimeter wavelength) beams off the comet's nucleus. According to Richard Goldstein of the Jet Propulsion Laboratory, his team obtained "a good signal" during observations Wednesday morning (May 11) and Friday night (May 13, when the beam took 70 seconds to travel out to the comet and back). "We analyzed the spectrum of the returned signal and tried some polarization experiments, but it'll take a while to look over the results."

Goldstein said that a good ephemeris is required in order to know where the comet is and where to tune the receiver. "But this comet wasn't observed very long and its orbit was not well known, so there was a lot of excitement in actually finding it." Goldstein's main concern now is trying to get time on the radio telescope for the close approach of 1983e, Sugano-Saigusa-Fujikawa, on June 12. "It's a good instrument, so there's always a long line."

The State of Planetary Exploration

NASA's planetary exploration funds fall into two areas: money to build and operate spacecraft and money to support scientific research. From the latter portion come the salaries of the scientists and funds for their computer time, laboratories, and telescopes. Without this support, the science portion of planetary exploration wouldn't exist.

Years of declining budgets have sliced deeply here, with disastrous results. A steady stream of researchers has left the field. Data from the Voyager Jupiter and Saturn encounters lie largely untouched. Future programs, such as the International Halley Watch, have been threatened.

Scientists would like to see spending for research returned to its 1981 level, $64 million, compared to $50 million for this year. They view the 1981 amount as the minimum, but they feel they can get by with it.

Getting the increase presents a problem because the largest cuts have come under the Reagan administration. This year's White House proposal recommends another reduction of 15%. Clark

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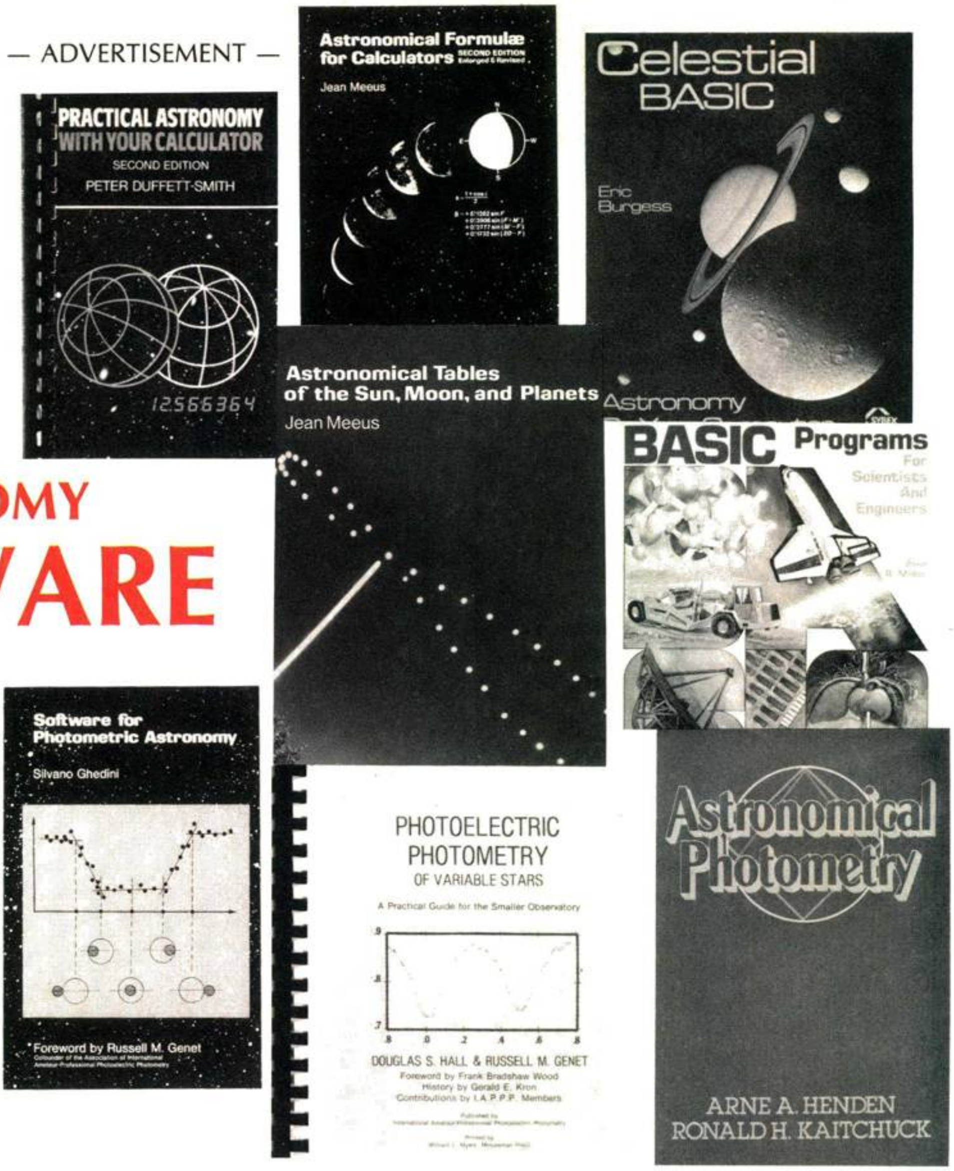
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ASTRONEWS

Chapman, Chairman of the American Astronomical Society's Division of Planetary Science, and his colleagues hope that Congress will not only ignore the proposed decrease but actually will increase spending over two years to the 1981 amount. Early congressional action indicates they'll get what they want.

The second item Chapman wants, money for a new mission, appears to be the bright spot. Just as the scientists need a certain funding level, so NASA's engineers need new mission starts every two to three years. Since 1976 the space agency has received permission to begin work on just two of the half-dozen craft it wanted. Galileo, a Jupiter mission, has scraped through several attempts to cancel it, but has survived. VOIR, a sophisticated mission to Venus, wasn't so lucky. It was born — and died — last year.

The Reagan administration claimed no malice toward the planetary program in killing VOIR. Rather, it felt the cost — some $600 million — was unreasonable. NASA took the hint, set a $300 million limit on the mission, and started redesigning. To keep within that limit, VOIR's ability to study the atmosphere and map details smaller than 100 meters had to go. The result calls for a craft built largely of spare parts, instead of VOIR's custom design. But the mission, now called the Venus Radar Mapper (VRM), can still provide the first detailed maps of the cloud-shrouded planet's rocky surface. VRM also has the blessing of the White House, which placed the project in its proposed 1984 budget.

The first two points on Chapman's "wish" list deal with immediate problems. The last, a continuing program, turns to the future. For the past decade, planetary scientists have tried to get Cadillacs out of a government interested in Volkswagens. By 1980 they were ready to try another approach. Under NASA sponsorship, a group of scientists began meeting to devise a modest-cost program for studying the Solar System.

This spring the Solar System Exploration Committee (SSEC) finished its task. Its report lists 14 projects to choose from over the rest of this century. The targets range from Venus (to be studied by VRM and later an atmospheric probe) to Uranus (a flyby with a probe for the planet's atmosphere). In between are targets like the Moon, Mars, Saturn, the asteroids, and a comet. NASA hopes to fly some 8 to 10 of these missions, budgets permitting.

Two things separate the SSEC's report from previous planning. First, it is a unified concept. Planetologists surveyed their field and picked a set of missions to advance their discipline across its entire breadth. Once the White House and Congress accept the plan, selling the individual pieces should be relatively easy.

Second, the SSEC picked its projects with price tags firmly in mind. Notably absent are such highly desirable — and highly expensive ($2 billion) — missions as gathering samples of Mars for return to the Earth. Instead, prices range from a moderate $300 million to an inexpensive $100 million.

To get these bargain prices, the committee cut each proposed project to its essentials. For example, the lunar orbiter NASA wanted several years ago would have carried nine experiments; the SSEC's version would carry five. The committee calculates that its entire program would cost some $300 million a year compared to the $186 million being spent this year. (At one time, $900 million in today's dollars was spent each year to explore the planets.)

The SSEC has left the scheduling and selection of individual projects to NASA. It has, however, listed its top priorities. The first is the Venus Radar Mapper, scheduled to reach Venus in 1988. After that the committee would like to see:

- A Mars geoscience/climatology orbiter to begin studies in 1990. As the name suggests, the mission would have twin objectives: it would measure the composition of the martian crust while recording the role of water in the martian climate.

This craft would be the first of a new breed — an Earth satellite modified for interplanetary endeavors. The method of funding would also be new. Until now, all planetary missions have been separate budget items. NASA would like to start a "Planetary Observer" program that would receive a steady $50 million per year. Each mission, with this as the first, would be paid for out of this fund.

- A comet rendezvous craft to fly beside a comet for several months sometime in the last half of the 1990s. Unlike the probes that will buzz past Comet Halley, this one would have time for in-depth studies of an object believed to have remained virtually unchanged since the formation of the solar system.

This craft too would be of a new breed — although it would be designed from scratch for low-cost solar system exploration. Modified versions of these so-called Mariner Mark IIs would conduct as many as half the missions on the SSEC's list. Each one, though, would need separate approval, unlike the Planetary Observers.

- A Titan probe and radar mapper would drop an instrumented probe into the saturnian moon's atmosphere and then map its surface with radar. Scheduled to arrive in the late 1990s, it could be the second Mariner Mark II craft to fly.

Success for the plan drawn up by the SSEC depends on an unspoken agreement. Politicians must provide support for a modest program of exploration, and scientists must be willing to settle for modest programs.

The Reagan administration has shown its tacit approval for the SSEC's approach by approving VRM. Planetary researchers in turn have already shown restraint. Last year NASA discovered that it could duplicate the Galileo Jupiter craft for the "fire sale" price of $100 million. The replica could be sent to orbit Saturn and probe its atmosphere — both items in the new program. Unfortunately, adding the Saturn mission would exceed the budget proposed by the SSEC. The committee voted to give up the chance to explore the ringed planet. The option isn't dead, but to revive it will cost more each year that it is delayed.

Now that the committee has made its recommendation, the emphasis shifts to NASA. The space agency is balancing the scientists' plan against engineering possibilities and fiscal probabilities. The final outcome should resemble the SSEC plan in outline, while differing in the details. *Van R. Kane.*

Comet Sugano-Saigusa-Fujikawa (1983e)

Just a week after the outburst of interest in Comet IRAS-Araki-Alcock, three Japanese amateurs discovered another bright comet. On May 8.75 UT, M. Sugano — sweeping the starfields in Andromeda — spotted a "diffuse and unconcentrated patch," but recorded it as bright as magnitude 7. Saigusa and Fujikawa each independently picked it up within hours, and Comet 1983e became Comet Sugano-Saigusa-Fujikawa.

At press time, not much is known about this icy ball of gas and dust. At about magnitude 6, Sugano-Saigusa-Fujikawa should practically "eclipse" M-31, the Andromeda Galaxy, on May 28. It should reach fifth magnitude with a noticeable tail by June 12, when it swings within six million miles of Earth. (Coincidentally, this is only twice as far away as Comet IRAS-Araki-Alcock's close approach on May 11.) It will then fade and move into the southern sky, passing out of view about mid-July.

This photograph of Comet Sugano-Saigusa-Fujikawa, taken just a day after its discovery, shows the seventh-magnitude nucleus and faint tail. Photo courtesy Brian Skiff, who used the 13-inch "Pluto" Camera at Lowell Observatory and 103a-O film for the 10-minute exposure.

Intergalactic Matter

Intergalactic space is usually considered void of matter. Recently, though, a team of Cornell University radio astronomers discovered evidence — the first — for a cold cloud of gas floating between galaxies. If its existence is confirmed, the neutral hydrogen cloud may have great significance to astronomers investigating the evolution of galaxies — it may represent a proto-galaxy that never formed stars.

Yervant Terzian, chairman of Cornell's astronomy department, Stephen Schneider, George Helou, and Edwin Salpeter were surveying gas clouds inside other galaxies with the 300-meter antenna in Arecibo, Puerto Rico. In order to calibrate the device, the astronomers set it to a position in the constellation Leo where there should have been no detectable emission. The emission accidentally picked up by the astronomers turned out to be from the edge of the cloud. The team then mapped the cloud's radio structure and measured its rotation.

At a distance of 30 million light-years, the outermost portions of the cloud appear to be rotating at a

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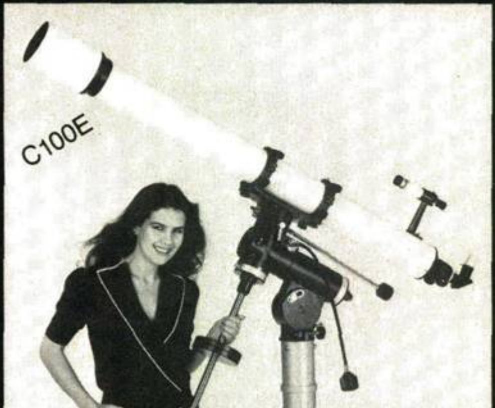

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velocity of 80 kilometers per second. The gas cloud is 300,000 light-years in length — three times the diameter of the Milky Way — and may contain more than a billion solar masses of hydrogen. The cloud's rapid rotation suggests that some invisible mass resides within, holding the cloud together against its great rotational speed. The central mass might be 100 times more massive than the hydrogen cloud itself, making the whole system as massive as 100 billion suns — the mass of an average galaxy. The central mass may be swarms of neutrinos, black holes, or non-radiating, very low mass stars.

If the cloud is truly isolated, it may be an artifact of the galaxy-forming phase of the universe. But before calling it primordial, astronomers must prove that it is not a fragment pulled loose during an encounter between two normal galaxies. The next step is an optical search of the region using long-exposure photographs.

The cloud's existence may affect what we know about the end of the universe, too. Already astronomers are arguing that it may represent part of the "hidden mass" of the universe. According to most astronomers, the easily visible universe is not massive enough to halt the expansion begun 18 billion years ago with the Big Bang. If intergalactic hydrogen clouds are fairly common, they may provide the remaining mass necessary to stop the expansion and start the universe collapsing in on itself.

Viking Lander 1: "Close the Book . . ."

Until last November, the Viking Lander 1 — its activities reduced to stationkeeping — was sending back to the Jet Propulsion Laboratory in Pasadena, California, a small but steady stream of data on the Red Planet's climate and weather. At that time, a skeleton staff of engineers — all that was left from Viking's heyday seven years ago — radioed its onboard computer a set of new commands as part of the normal monitoring routine. But when the craft failed to acknowledge the commands, the engineers began to worry.

Now, after months of rummaging through old manuals, questioning former Viking staff members, testing remedies, and waiting to see if the craft would use a preprogrammed routine for contacting Earth, they have given up. For whatever reason, the last of the Viking craft at Mars has fallen silent — almost certainly for good.

According to Viking Project Manager George N. Gianopulos, the engineers have eliminated all possibility that the trouble occurred in the batteries, the antenna-pointing software, or in the transmitter — the three most likely candidates for failure. Had the problem been in any or all of these areas, the engineers probably could have restored contact with the craft. Instead, some other as yet undetermined difficulty, either by itself or in conjunction with one or all of the other three areas of concern, has rendered Viking mute.

Although there is a very slight chance the Lander may spontaneously begin to transmit again, NASA has decided to stop listening and not to gather staff for any heroic attempts at reviving it. The reason? The possible returns would not repay the large efforts required — and there is only the remotest chance of success, anyway. Farewell, Viking!

ASTRO CALENDAR

July 26-30	**ALCON '83** — national convention of the Astronomical League. Jacksonville, Florida. Contact: Michael Reynolds, P.O. Box 1170, Jacksonville Beach, FL 32250.
August 5-6	**Stellafane.** Springfield, Vermont. Contact: Dennis di Cicco, 60 Victoria Rd., Sudbury, MA 01776.
August 12-13	**5th Annual Amateur Telescope Makers Contest (CAFTA).** Montreal, Canada. Sponsored by La Societe d'Astronomie de Montreal. Contact: CAFTA, c/o Michel St-Onge, Box 206, Station St-Michel, Montreal, Quebec, Canada H2A 3L9.
September 5-9	**First International Conference on Ethnoastronomy,** "Indigenous Astronomical and Cosmological Traditions of the World." Smithsonian Institution, Washington, DC. Contact: Ethnoastronomy Conference, Center for Archaeoastronomy, University of Maryland, College Park, MD 20742.
September 30-October 2	**Astrofest '83.** Sponsored by the Chicago Astronomical Society. Contact: Astrofest, P.O. Box 596, Tinley Park, IL 60477.
October 8	**Telescope User's Clinic.** Sponsored by the Western Observatorium. Rio Hondo College, Whittier, California. Contact: Western Observatorium, 13215 E. Penn St. #411, Whittier, CA 90602. Phone Bob Ferguson at (213) 795-4181.
October 17-20	**15th Annual Meeting of the Division for Planetary Sciences of the American Astronomical Society** (professional meeting). Sheraton Conference Center, Ithaca, New York. For information about travel and accommodations, contact: Joseph A. Burns, Space Sciences Building, Cornell University, Ithaca, NY 14853. Send titles (by August 1) and abstracts (by August 15) of proposed papers to Steven J. Ostro, program chairman, at the same address.
October 21-23	**AAVSO Fall Meeting.** Nantucket, Massachusetts. Host institution, Maria Mitchell Observatory. Contact: Janet A. Mattei, AAVSO, 187 Concord Ave., Cambridge, MA 02138. Phone (617) 354-0484.
October 27-29	**Great Plains Planetarium Association Conference.** Hastings, Nebraska. Contact: Mitch Luman, J.M. McDonald Planetarium, 1330 N. Burlington, Hastings, NE 68910.
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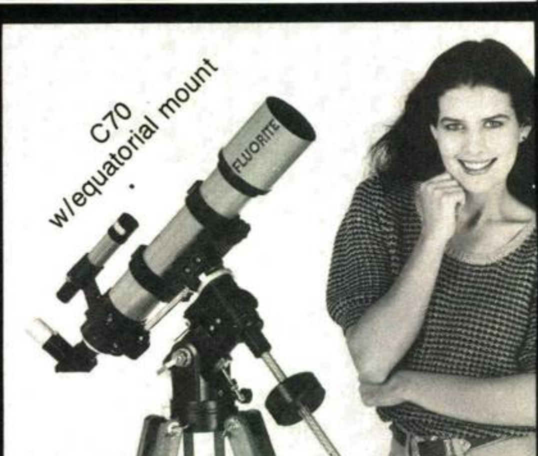
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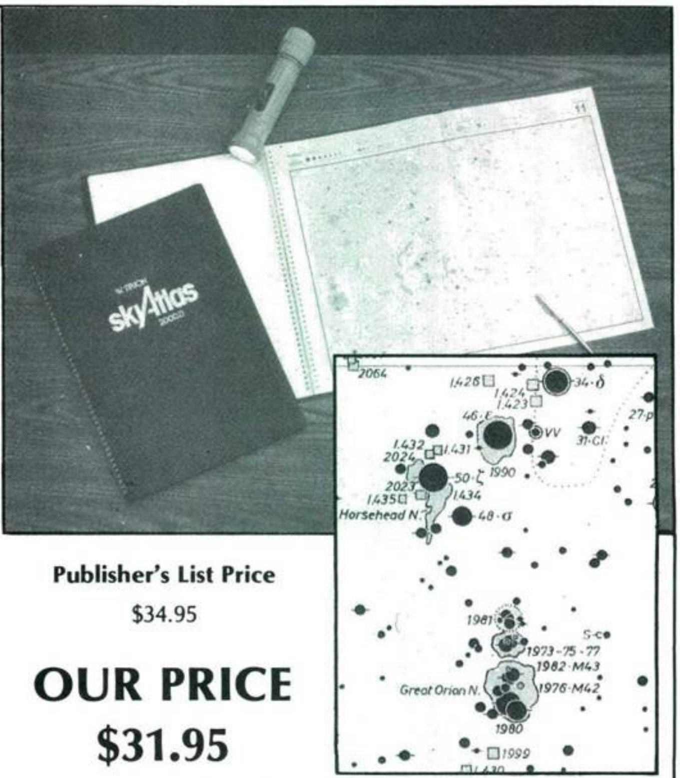

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Mystery Star

by David Darling

For more than 80 years, one star has ranked high among the great stellar mysteries. Its history is littered with the remains of ingenious theories that tried to explain its drops in brightness. Like all good mysteries, Epsilon Aurigae hides its secrets well — astronomers must delve into its shroud of fascinating, yet elusive clues. An orbiting cloud of meteors, a protostar, a nova remnant, a black hole — such hypotheses are its legacy. Even now, as it dims for the seventh time since its variability was recognized, the nature of this bizarre stellar system remains unknown.

You might never notice this star's variability, even after a lifetime of sky-watching. First of all, third-magnitude Epsilon Aurigae is fairly faint, outshone by scores of other stars. In fact, one attention-getting stellar rival lies just 3° to the northeast — Capella, the constellation's brightest star. But assuming that its modest visual appearance doesn't put you off, the extreme rarity of Epsilon Aurigae's changes presents a more serious obstacle — for the star drops to a minimum brightness of about magnitude 3.7 only once every 27 years. Although minimum light lasts nearly a year, the change occurs so slowly that only the keenest observer would notice anything unusual.

Not surprisingly, Epsilon Aurigae's pedestrian light changes went unnoticed for many years. The painfully slow variations were finally recognized by J.H. Fritsch, a German pastor and amateur astronomer, who happened to be watching when the star reached minimum in 1821. Another minimum was seen in 1848, recorded by observers such as Julius Schmidt in Athens and Friedrich Argelander in Bonn. These German astronomers provided the first visual estimates of the star's range in brightness; they came close to today's accepted value of 0.8 magnitude. In 1876, Epsilon Aurigae dimmed once more.

Not much was known about the star by the end of the 19th century, even after three recorded minima. Prior to 1900, there just weren't enough observational data to determine what caused the variations in light output. In star catalogs of the time, Epsilon Aurigae was incorrectly labeled an irregular variable — a star that brightens and dims as a result of unpredictable internal events. Astronomers needed new observations to uncover the real reason for this star's light changes.

Right up to the start of this century, photometric measurements were the only available data on Epsilon Aurigae. Although these measurements are vital, they reveal only a small fraction of the information stored in a trickle of starlight. Photometry deals with quantities of light — an object's brightness and the way its brightness changes over time. It tells nothing of the *quality* of light and reveals none of the complex details of a stellar spectrum. Spectroscopy, on the other hand, deals directly with the basic structure of incoming starlight. For stars, spectroscopic measurements can uncover vast amounts of information on internal properties (such as composition and temperature), external properties (such as motion through the Galaxy), and stellar environments. Around 1900, these techniques were first applied to Epsilon Aurigae. Within three years the basic cause of the star's variability was uncovered.

One of the important stellar properties revealed by the spectroscope is a star's *radial velocity* — its motion along our line of sight. It rarely represents the total velocity since the star's actual motion is unlikely to run exactly along the line of sight. Emission and absorption lines in a star's spectrum reveal this movement. For an object moving away from an observer, these spectral lines appear shifted toward the red end of the spectrum when compared to the wavelengths of the same lines in a laboratory; similarly, motion toward the observer creates a wavelength shift toward the blue end of the spectrum. (The effect was first described by Christian Doppler in 1842 and is commonly known as a *Doppler shift*.) By measuring the amount by which these lines are displaced, astronomers can determine the component of a star's motion that is directed along our line of sight.

When astronomers made the first spectroscopic measurements of Epsilon Aurigae, they found the usual displaced spectral lines that indicated the star's line-of-sight motion. But these observations also showed that the spectral displacement varied with time — the star's velocity was changing. One of the first observers of Epsilon Aur's strangely shifting lines, Potsdam Observatory astronomer H.C. Vogel, knew precisely what this meant.

In 1889 Vogel was the first to photograph the spectrum of Algol, another star whose brightness periodically varies. Algol's spectrum, like that of Epsilon Aurigae, showed spectral lines with regularly changing displacements. The cycle of spectral line changes had precisely the same period as Algol's changes in brightness — 68 hours, 45 minutes. If interpreted as a Doppler shift, this meant that Algol alternated between moving away from us and moving toward us. Vogel solved this riddle by suggesting that Algol was no solitary sun, but a binary system whose orbital plane happened to lie along our line of sight. Algol was the prototype for a whole new class of variables, one whose brightness changed because of successive stellar eclipses. The shifting spectral lines came from the bright star in the Algol system, and a larger, but much dimmer, companion orbited it. Since the system's orbital plane is aligned with our line of sight, its fainter member passed between the bright star and Earth. This eclipse cut off the bright star's light, creating the primary dimming of Algol. (See "The Wink in the Demon's Eye," ASTRONOMY, December 1980.)

Could Epsilon Aurigae be another of these eclipsing variable stars? It shares with Algol the basic prerequisities: varying line displacement and large brightness changes. But while Algol's period was short and fairly accurately known, the very existence of periodicity in Epsilon Aurigae's variations was not — after all, the star was classified as an irregular variable! Its period was hidden in the records of Epsilon Aur's minima, but it hadn't struck Vogel, even after observing the star's slowly changing spectral lines for two years.

Confirmation of Epsilon Aurigae's periodicity finally came in 1903, around the time of the star's fourth observed minimum. By examining both historical records and the details of the most recent minimum, German astronomer H. Ludendorff pinned down the period of light fluctuation to a staggering 27.06 years. By combining photometric and spectroscopic observations, Ludendorff proved that Epsilon Aurigae was indeed an eclipsing binary. Its 27-year orbital period was the longest then known.

This lengthy orbital period didn't bother Ludendorff and his contemporaries, but the tremendously long duration of its eclipses did. Based on photometric results of the 1902-1903 eclipse, the minimum clearly lasted about a year, sandwiched between two six-month periods of partial eclipse. For one whole year, the brighter star of the system was totally eclipsed behind some mysterious companion.

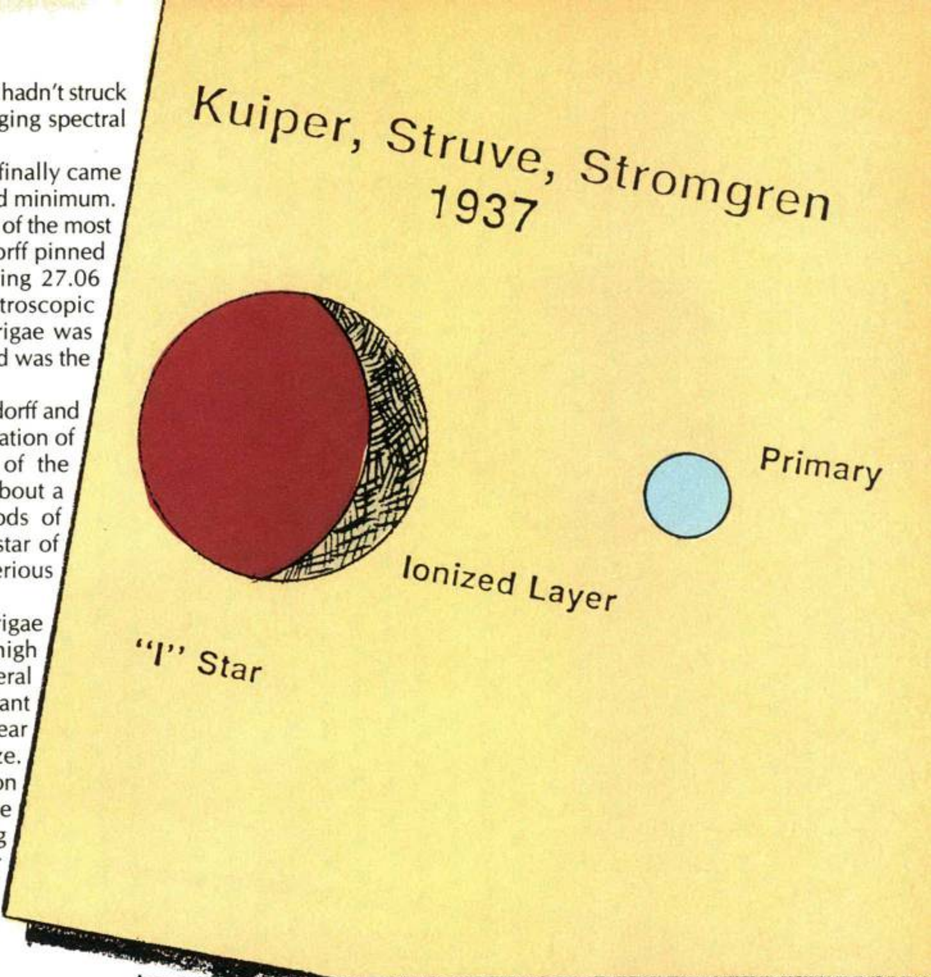
The bright star — the primary — of Epsilon Aurigae is an F2-type supergiant, a star of low density and high luminosity. This star is also very big, probably several hundred times larger than the Sun. For such a giant star to be totally eclipsed for the best part of a year requires an eclipsing body of extraordinary size. Rough calculations show that the unseen companion must have a radius almost 3,000 times that of the Sun, or approximately 2 billion kilometers. Putting this object in the Sun's place, it would fill the solar system out to a distance greater than the orbit of Saturn. And the companion might not be a star at all.

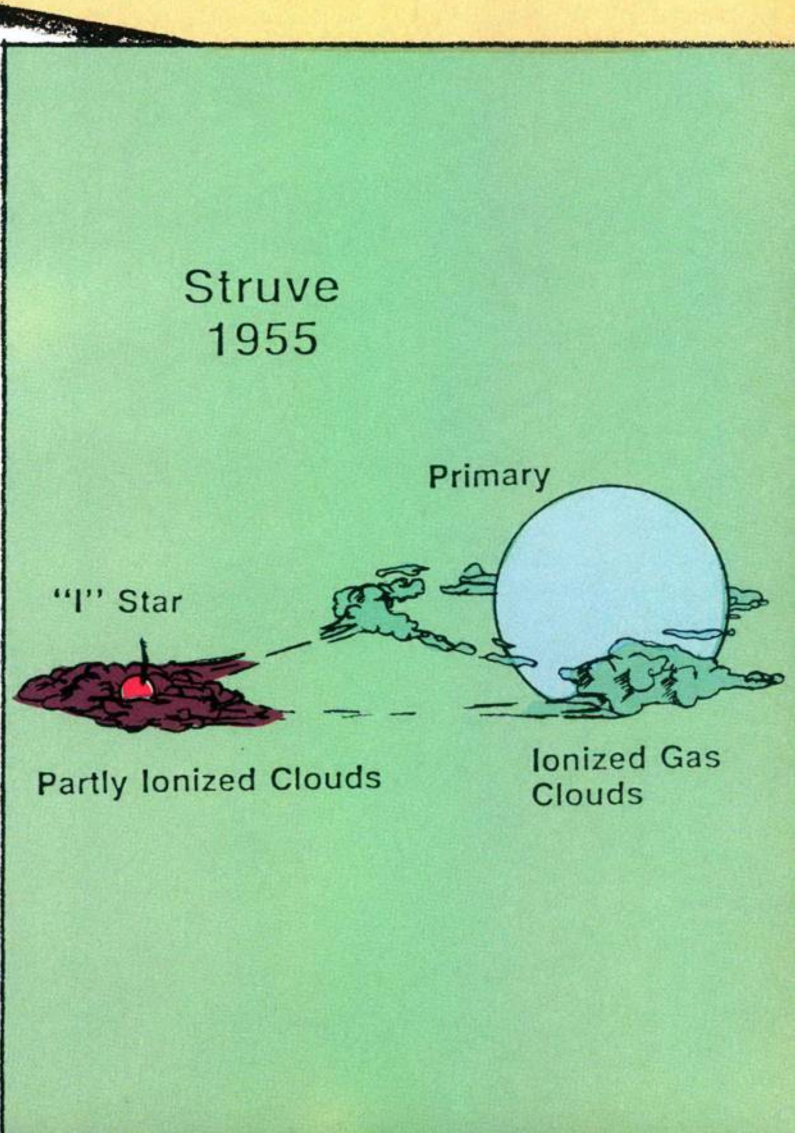
For instance, Ludendorff himself suggested in 1924 that the mystery body might be a swarm of meteorites. Based on its effect on the primary's orbit, however, and on an assumed distance of about 2,000 light-years, the mass of his meteorite swarm would have to be ridiculously large — somewhere between 10 and 20 solar masses.

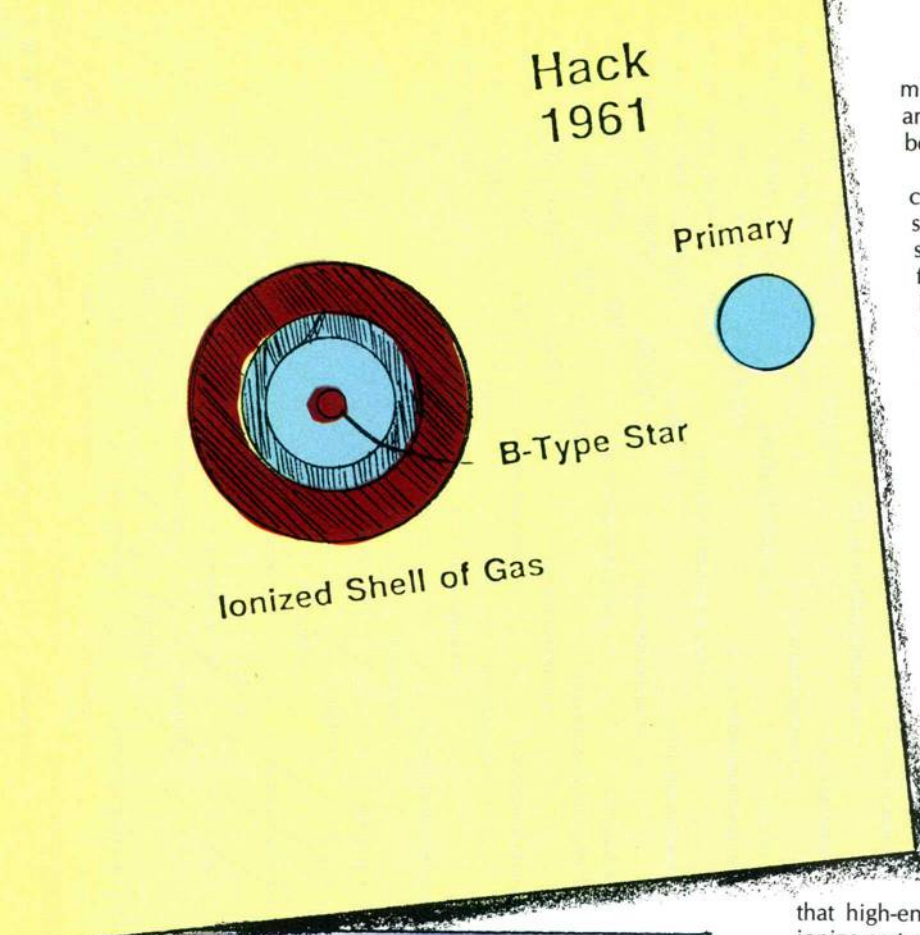
The mystery of Epsilon Aurigae persisted and deepened. Following observations of the 1928-1930 eclipse, it became obvious that this system contained one of the most peculiar objects ever encountered. The light of the visible star, the supergiant, was dimmed equally in all wavelengths at minimum. Such a wavelength-independent eclipse is exactly what you would expect if the occulting object is opaque, such as a star. A plot of the changes in Epsilon Aur's brightness during eclipse — a light curve — supported this idea. The year-long minimum is fairly deep — a drop in brightness of about 0.8 magnitude. This corresponds to a factor of about 2 in brightness, so minimum light cuts Epsilon Aurigae's usual luminosity in half. Both the light curve and the eclipse's wavelength independence suggested that the companion was an enormous star of low surface brightness.

Yet observations of this eclipse left astronomers with an unsettling paradox. Epsilon Aurigae's spectrum at minimum was virtually identical to that observed outside eclipse, indicating that the primary star is never totally eclipsed by its bizarre mate. Characterized by the spectral lines observed and recorded outside of the eclipse, the light from Epsilon Aurigae shone *through* its companion even at minimum light.

The mysterious eclipsing body might be a star with a spectrum identical to the primary's. During the eclipse of the primary, the companion would essentially substitute its own absorption lines, fooling astronomers into thinking that they really originated in the eclipsed star. It sounds good, but there are at least three strong arguments against this suggestion. First, the companion's spectrum was never detected, even when it should have been well separated from the primary. The second objection centers around the light curve of the system. If the companion were a normal star, a minimum would occur when it passed behind the primary. Astronomers found no such secondary







minimum. Finally, the primary itself is a variable star, and displays its 120-day semi-regular light changes before, after, and *during* eclipses by the companion.

Epsilon Aurigae was indeed an astronomical contradiction. In some ways its companion seemed star-like. Besides having a large size and mass, the secondary displayed Doppler-shifted spectral lines from the primary during the eclipse's partial phases. Light from the primary passing through the outer atmosphere of a rotating companion star would easily explain this observation. But what kind of star would allow background light to pass right through it? And what sort of star might avoid detection at visible wavelengths?

In 1937, Gerard Kuiper, Otto Struve, and Bengt Stromgren of the Yerkes Observatory suggested that the dark object in Epsilon Aurigae might be an extremely cool and tenuous object. They called it the "I" (infrared) component since it would emit all of its radiation in the far infrared. The I star's exceptional properties included a surface temperature of only 1,000° Kelvin and a density as low as the best laboratory vacuums. Unfortunately, near-vacuums aren't particularly effective in blocking out light; the infrared star's tenuous atmosphere would do nothing to cut down the supergiant's brilliance at eclipse.

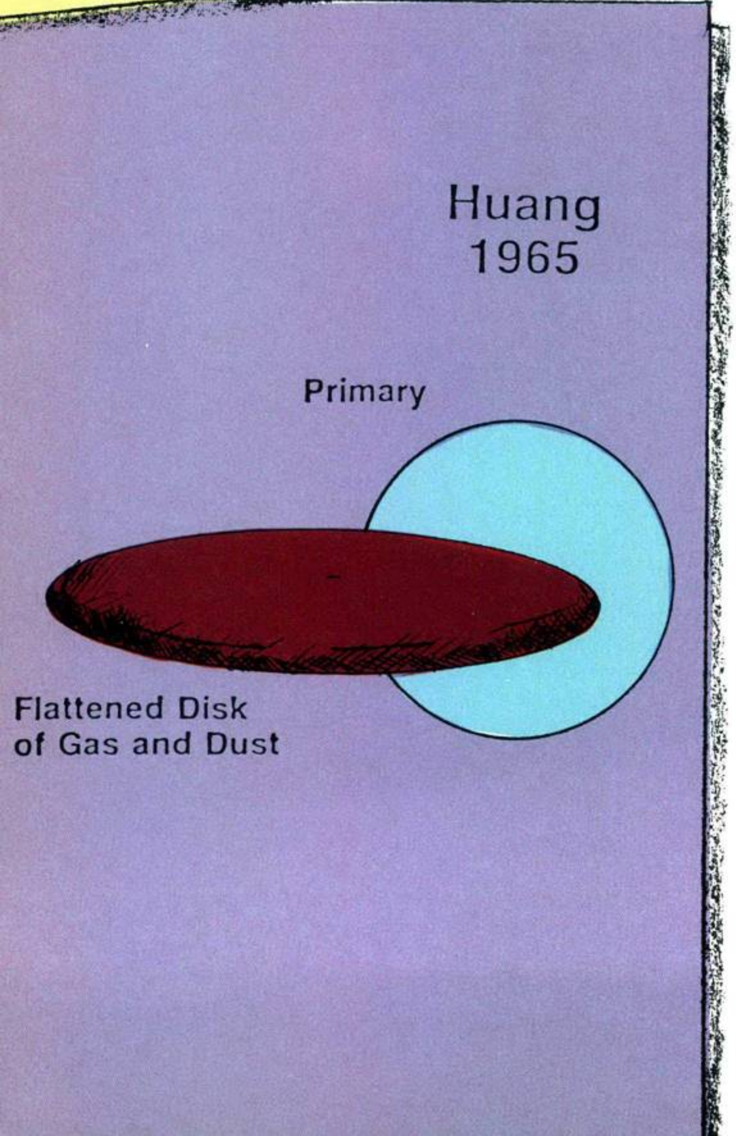
In an attempt to circumvent the problem, Kuiper, Struve, and Strömgren suggested that the I star might form an "ionosphere" due to the primary's intense radiation. They argued that high-energy ultraviolet light from the supergiant would ionize part of the secondary, releasing electrons from the atoms binding them. Since free electrons are excellent scatterers of light, the I component's ionosphere would dim the supergiant's light by scattering it into space.

Under detailed analysis, though, this model broke down. The distant primary could not liberate enough electrons necessary to account for the observed minimum. What's worse, infrared studies of Epsilon Aurigae failed to find any trace of the I star.

Struve came up with a new theory in 1955. This started a trend away from the "big star" ideas of Epsilon Aurigae's companion. Struve's new model placed a star of normal size in orbit around the bright supergiant — but now each star was surrounded by ragged belts of moving gas clouds.

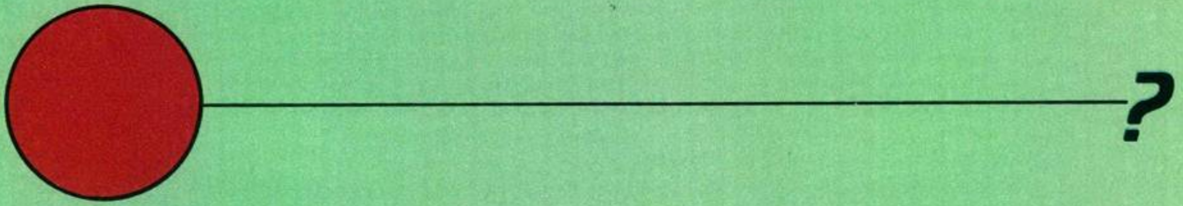
Struve argued that the primary was so big and bright that the retinue of gas clouds left its light virtually unaffected. The much smaller and dimmer companion, on the other hand, would be shrouded from view, its light too feeble to penetrate the gaseous cocoon. In this new model, the gas clouds around the small companion were made opaque by ionizing radiation from the primary. This model avoided the main problem of the I star theory since Struve allowed portions of the companion's gas belt to approach the supergiant. These gas clouds would orbit close enough so that the F star's intense ultraviolet light could free a great number of electrons — so many that about half of the primary's light could be scattered from our view.

Both the I star model and Struve's gas cloud theory used the same basic process — electron scattering — to create the eclipses. As it happened, Struve's gas cloud theory didn't survive long after the 1955-1957 eclipse. But the idea that the eclipses were probably due to the scattering of light by electrons remained, incorporated into yet another model of Epsilon Aurigae proposed by Margherita Hack in 1961. She assumed that the companion — this time a hot, young B-type star — was surrounded by a huge tenuous ring of gas, possibly blown off the star during an earlier nova-like explosion. In any event, her idea is novel because in it the companion, not the primary, produces free electrons by photoionization of its gaseous shroud. Once again, electron scattering makes the gas opaque. The youthful secondary, with a surface temperature of 20,000° K,



Distance	around 0.6 kpc (2000 light-years)
Orbit	
Period	9886d (27.1 years)
Inclination to Celestial Sphere	approximately 72°
Separation	24 - 35 AU (3.6 to 5.2 billion km)
Duration of eclipse	
Minimum	330d
Total (minimum plus partial phases)	714d

Present eclipse ends June 1985



Visible Component		Companion
F2 supergiant (blue-white)		
about 3,500°	Surface temperature	less than 1500° K
30 to 85 $D_\odot$	Diameter	around 1000 $D_\odot$
15 to 35 $M_\odot$	Mass	10 to 20 $M_\odot$

Ranges reflect minimum and maximum values quoted in recent papers.

would create its own ionosphere in the circumstellar nebula.

Hack's model got a strong boost 18 years later, in 1979, when the International Ultraviolet Explorer satellite, together with balloon-borne instruments, confirmed the existence of a "hot spot" adjacent to the primary. Today, Hack's explanation ranks among the best available for explaining Epsilon Aurigae's behavior.

But electron scattering is not the only way to dim the primary's light. Another group of astronomers argues that grains of dust, not electrons, dim the light of Epsilon Aurigae's supergiant. The "dust absorber" theories are at least as fascinating as the "electron scatterers." One of the earliest was the brainchild of University of Manchester astronomer Zdenek Kopal. Kopal proposed that the supergiant's dark companion was a star that had not yet begun to shine — a proto-star. In Kopal's model, an accretion disk surrounds the infant star, a flat dusty nebula that might one day give rise to a planetary system. Small dust grains in this accretion disk — not ionization induced by the bright supergiant — soak up the primary's radiation during eclipse.

This idea looked promising. And the appearance of "ripples" in the 1929 and 1956 minima seemed to offer some observational support. These tiny light fluctuations might be caused by small, dense concentrations in the accretion disk — possibly proto-planets.

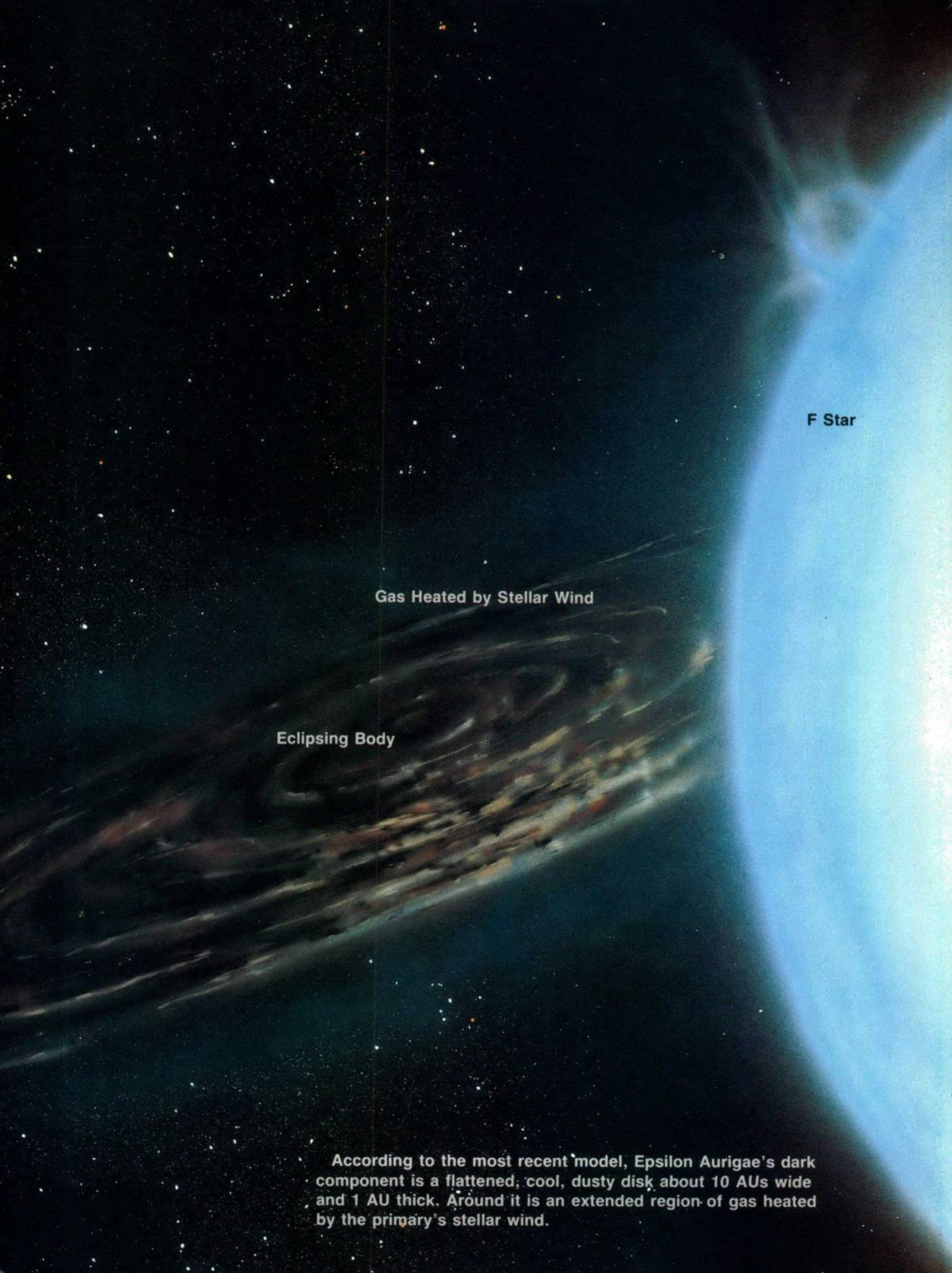
Su-Shu Huang took Kopal's concept a step farther in 1965. He was the first astronomer to attempt to re-create the observed eclipse light curve by making reasonable assumptions about the accretion disk. Huang developed a model in which the eclipses of Epsilon Aurigae were caused by a wide, flattened, totally opaque disk of dusty material. It completely hid the embedded star and blocked a portion of the supergiant during an eclipse. To get the general picture, imagine a frisbee (the accretion disk) eclipsing a balloon (the primary).

Huang's theory seemed to explain all of the eclipse observations. Minimum occurred when the disk was centrally located and obscured about half of the supergiant. Partial phases developed when the disk moved toward or away from its central eclipse position. The size and opacity of Huang's disk well accounted for the eclipse light curve. Now, however, the supergiant presented a problem. If Huang was right, the primary must have a radius of about 120 million kilometers — nearly the radius of Earth's orbit, and uncomfortably large for an F-type star.

Astronomers had to modify Huang's solid-particle disk in order to trim down the F star's size. By replacing Huang's totally opaque disk with one that had semi-transparent edges, the supergiant's size decreased considerably. The primary's new radius — between 44 and 81 million kilometers depending on the distance assumed — was more consistent with theoretical expectations.

The most controversial aspect of the accretion disk models concerns the origin of the disk and the nature of the embedded object. Kopal made no bones about this: in his view, the accretion disk was without question a proto-planetary nebula. In its core sat a star in the process of formation. Fluctuations in the two most recent minima were probably caused by embryonic planets, objects still condensing from the nebular "soup."

More recently, some theorists have disputed Kopal's "solar nebula" interpretation. Alistair G.W. Cameron and Richard Stothers argued that the companion might be an old, dead star. Instead of forming a planetary system or a newborn star, the material in the accretion disk may eventually plunge into the gravitational abyss of a black hole.


F Star
Gas Heated by Stellar Wind
Eclipsing Body

According to the most recent model, Epsilon Aurigae's dark component is a flattened, cool, dusty disk about 10 AUs wide and 1 AU thick. Around it is an extended region of gas heated by the primary's stellar wind.

But where did the accretion disk come from? Since the bright supergiant orbits far from the black hole, this material probably wasn't stripped from its atmosphere. But imagine that, long ago, the companion star of Epsilon Aurigae was brighter and more massive than the supergiant. Imagine that today's darkly shrouded companion used to be the primary. More massive than its mate, it would have evolved far more rapidly — perhaps even reaching its terminal evolutionary stage before the supergiant left the main sequence. Eventually, when the companion collapsed, it formed an incredibly dense object.

Cameron assumed that the companion was a rapidly spinning object. Debris thrown out in a failed supernova blast might then have escaped to form a disk structure. The collapsed object — probably a black hole, given the companion's present high mass — would be surrounded by an accretion disk made of matter shed from its outer layers.

Evolved, massive stars are rich in heavy elements forged at the high temperatures in their cores. These substances would condense into solid particles in the relatively dense regions of an accretion disk. And these solid particles, these dust grains, are what Cameron suggests cause the eclipses of Epsilon Aurigae.

So many theories — and such diversity of opinion on the nature of a single star system! Does any one account for the observational data better than the others? No — at this stage, the debate over Epsilon Aurigae is still wide open. There are pros and cons to all the major models.

Championing the electron scatterers is Hack's model — in which the companion is a hot, young B star surrounded by an immense low-density shell of gas. Hack suggests that the circumstellar ring is ionized — hence made opaque — by high-energy radiation from the companion. And a hot, ultraviolet-emitting object *does* orbit the primary. Hack's ionized gas cloud should have the effect of polarizing the primary's light. Until very recently, no such effect had been observed.

On the other hand, there are the dust absorbers. These models build various cases for a dust-strewn accretion disk as the eclipsing body, and it is the absorption of light by dust, not its scattering by electrons, that dims the primary's light. But what happens to the dust as it absorbs radiation from the primary? It should become heated, giving off substantial amounts of infrared radiation. By 1973, instruments sensitive enough to detect an "infrared excess" were in use, and astronomers found more infrared radiation than the primary star alone should produce. Modern infrared measurements suggest a lot of dust in the secondary component of Epsilon Aurigae.

Perhaps the most fascinating of the suggestions — again involving dust absorption — are those that propose a black hole companion and its accretion disk. If Epsilon Aurigae's companion actually is a *collapsar*, it should create highly variable X-ray emission from the surrounding accretion material. The X-rays, given off by frictionally heated gas in the inner parts of the accretion disk, would be easily detectable by a suitable orbiting observatory. Oddly enough, though, Epsilon Aurigae was never examined for X-ray emission, and the most recent opportunity passed by with the expiration of the Einstein satellite observatory. Nevertheless, most astronomers do not consider Epsilon Aurigae a very good black hole candidate.

So the nature of Epsilon Aurigae's dark eclipsing companion remains unknown. Yet even as you read this, another eclipse is in progress. Perhaps we are on the verge of solving the puzzles of this star, but let's remember that Epsilon Aurigae has seen the rise and fall of many apparently reasonable theories in the past. As Otto Struve wrote in 1962, its history is "in many respects the history of astrophysics since the beginning of the 20th century." With this kind of track record, Epsilon Aurigae will spring a few more surprises before finally revealing its secrets.

David Darling holds a Ph.D. in astronomy from the University of Manchester (U.K.) and is a computer consultant and a freelance science writer. His last article for ASTRONOMY was "The Quest for Black Holes" in the July 1983 issue.

ECLIPSE UPDATE

In July, 1982, the mysterious secondary of Epsilon Aurigae once again passed between its primary star and Earth; once again, a new generation of detectors and astronomers began examining the system's eclipse. "The new data hint at characteristics that were never before observed," notes Robert Stencel of NASA's Astrophysics Division. Infrared photometry, ultraviolet spectroscopy, and polarimetry measurements may provide the breakthrough needed to understand Epsilon Aurigae's invisible component.

James Kemp of the University of Oregon first observed polarized light from the system last December. Normally, light waves vibrate randomly around their direction of motion. Light vibrating non-randomly — that is, in preferred directions — is polarized. A polarizing substance transmits only light with vibrations in one direction. Kemp found a sudden change in the polarization of Epsilon Aurigae's starlight last December, about the time the secondary completely covered part of the visible star. This polarization could occur when light from the primary shines through dust grains aligned by a strong magnetic field.

But that's not all. The degree of polarization changes regularly with a period of about 70 to 80 days, suggesting a connection to the pulsations of the system's Cepheid-like primary. Unfortunately, the primary's pulsation period is 110 to 120 days — a close match, but not quite twice the polarization period. "Frankly," adds Kemp, "I don't know *what* this means."

In addition, polarimetry suggests that something within the system is tilted 30° to the orbital plane. The primary's rotational axis could be inclined, although it doesn't quite explain the observations. An inclined secondary component is the other obvious explanation. "But the best explanation for the light curve is an eclipse by an optically thick disk viewed edge on," says Kemp. "If it's tilted 30 degrees," he adds, "its hard to see how you'd get a flat minimum at mid-eclipse."

Ultraviolet spectroscopy with the IUE satellite shows very steady emission from singly ionized magnesium. According to Stencel and his co-workers Robert Chapman and Yoji Kondo of NASA's Goddard Space Flight Center, the constancy of this emission suggests that it comes from an extended region around the secondary component little affected by the eclipse.

Meanwhile, at the other end of the electromagnetic spectrum, Dana Backman of the University of Hawaii's Institute of Astronomy watched the infrared excess of Epsilon Aurigae increase as the eclipse progressed. As the primary's light is cut off, more and more of the infrared emission observed comes from the system's secondary component. For wavelengths from 0.3 to 20 microns, the eclipse is still wavelength independent. If the eclipsing object is not semi-transparent, says Backman, "then it's very opaque — like a brick wall." If the secondary is semi-transparent and has no sharp boundaries, Backman's photometry indicates that its particles are larger than 20 microns, or about 100 times the size of run-of-the-mill interstellar dust grains.

What does all this mean? No one knows just yet. Results from the ultraviolet suggest a very cool object (below 1,500° Kelvin) with a halo of hot dust. This agrees with Backman's results from the infrared, which suggest a temperature of about 650° K for the secondary.

Piecing together data from the first half of the eclipse, the secondary appears to be a cool object, perhaps with a well organized central core. This would account for the infrared photometry and the jump in polarization. One problem in this picture is the detection of ionized magnesium. How can a cool object harbor ionized material? Since the emission remains constant during the eclipse, it might come from an extended region around the secondary's disk. This material is heated by the stellar wind of the hot primary.

Although it works well for most of the new observations, this model does not explain the cyclic polarization changes Kemp observes. Also, spectral contributions from the pulsating primary are poorly known. Continued photometry of the system is vitally important in order to relate any spectral changes to the Cepheid-like pulsations.

Slowly but surely, Epsilon Aurigae is revealing its mysterious companion. While astronomers try to determine what the first half of the eclipse told them, the strange object moves along in its orbit. This seventh eclipse is far from over, and astronomers eagerly await more surprises from this stellar mystery.

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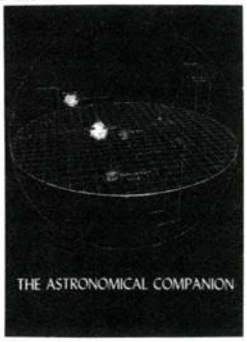

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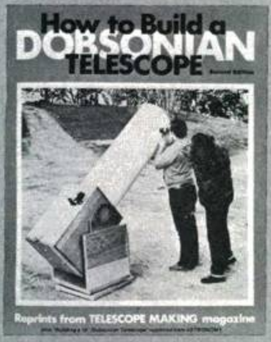
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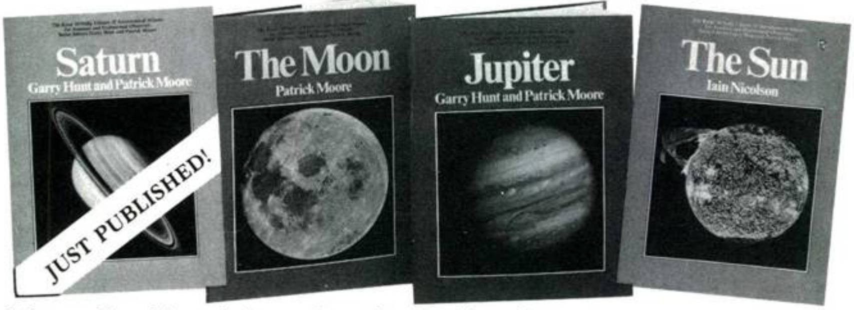

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amateur astronomy and the home computer

equipment atlas

by

Dennis Chamberland

The marriage of home computers to backyard astronomy sounds perfect. After all, mechanical computers and other calculating devices have been in the hands of astronomers at least since the days of Ptolemy. Given the right combination of knowledge and equipment, amateur astronomy and computers can have a productive and long-lasting relationship.

But anyone who rushes ahead willy-nilly and buys into a system blindly is running an awfully big risk of disappointment — and of losing a wad of cash in the process. The single most important step in linking a computer to your astronomical hobby is having good reasons to do it at all. Be critical: something that sounds good may never produce really worthwhile results. So take a close, hard look at what you want the machine to do.

All the Wrong Reasons

Despite all the publicity about home computers, there is still a fog of misinformation about them. The reputed abilities of computers in general and the actual abilities of computers you can afford usually differ by a lot. To help clear up the misconceptions, here are a few of the things the home computer *cannot* do (yet):

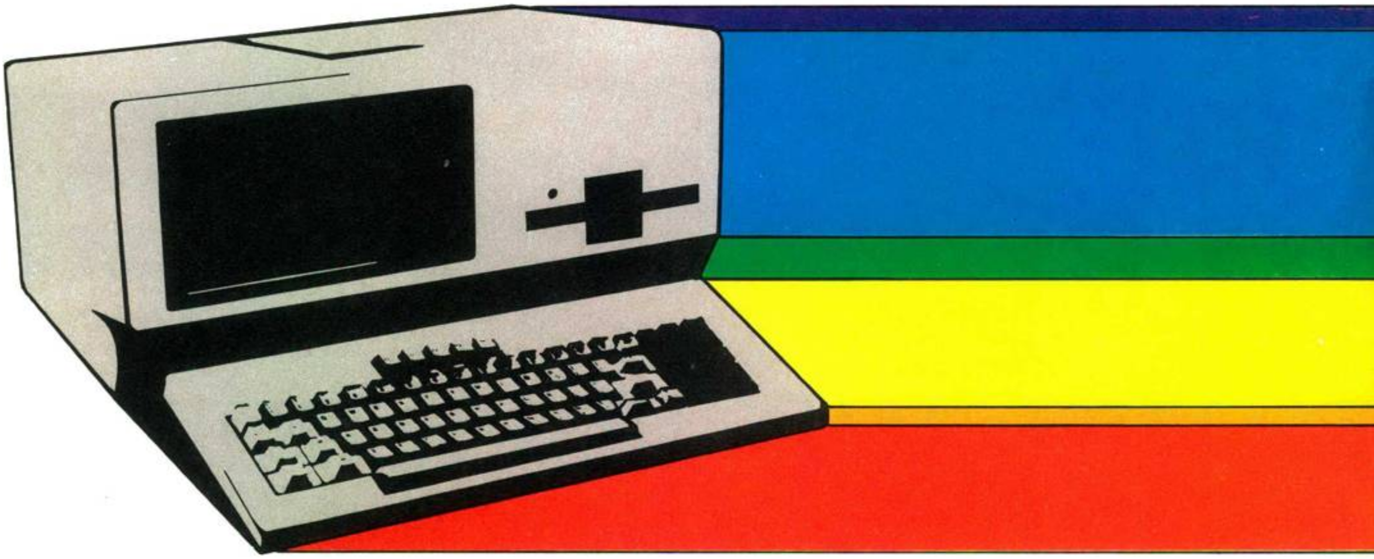
1. Without considerable expense and expertise on your part, your home computer will not point your telescope toward a given astronomical body.
2. It cannot store images for later playback.
3. A home computer will not observe for you and alert you if it detects something unusual like a nova, a new comet, or an asteroid.
4. It will do nothing to increase the sensitivity of your scope — or improve its resolution.
5. It won't keep your eyepieces clean and dust-free — nor will it wash the car or walk the dog. . . .

All right then, what good *are* the darn things? Well, a computer can calculate the rise, set, and visibility of celestial objects, provide coordinates for planets and the Moon, calculate the circumstances of an eclipse, predict exposure times in astrophotography, help you design a telescope, organize your observation log, store information on celestial objects and recall it in seconds, calculate this . . . display that. . . . But you begin to get the idea. In short, a computer helps you enjoy astronomy more fully. Before we explore the whats and the hows in greater detail, let's first examine a thorny question: How much should you spend?

How Much Is a Lot?

I'm not going to tell you what kind of computer to buy — that's a question you have to settle for yourself, following a thorough, hands-on examination of needs versus specific computer capabilities. When you have done that and are ready to select a computer, you'll probably be spending anywhere from about $500 (for a minimum system) through $2,500 to $4,000 (for a medium-size system) up to $7,000 to $10,000 (for a Rolls-Royce version).

Yes, you can find computers starting at $50 or less. But as they come, straight from the box, these machines are too limited to accomplish anything significant. In practice, you'll find that to get a useful system, you have to buy a few "extras" — like a monitor viewing-screen,



additional memory, and some storage device (either a tape or disk drive). In the end, these "extras" will push the total figure closer to $500 than the $50 you started with.

The key to buying a computer and being happy with it lies largely in planning for expansion from the very beginning. When you select the equipment (hardware), look for systems with *true expandability*. True expandability differs markedly from *advertised* expandability in that it will accept many hardware add-ons that do not necessarily come from the manufacturer. True expandability means that the computer's memory can be expanded *by the owner* to the maximum its microprocessor can handle. (Sending it back to the factory for a "brain job" doesn't count.) True expandability also means that the system can accept a variety of memory-storage devices such as floppy or hard disk (Winchester) drives.

In addition, it's sensible to get a computer that uses the CP/M operating system. CP/M has become the standard among microcomputers and gives you access to a very large library of already written programs (software).

By the time you've finished looking around, your shopping list of equipment should contain a computer with keyboard, a monitor or TV viewing-screen, a single or dual floppy-disk storage system, and perhaps a printer. You can get by at first with a cassette-tape storage system and without a printer, but sooner or later you'll want to add them.

Software

There are basically three ways to get astronomy-related programs. First, you can buy the software already recorded on a floppy disk or cassette tape, ready to insert into your machine and run. But these programs must be formatted or coded for the specific machine you have, and not all machines have astronomy software designed for them. Moreover, the programs may not be as versatile or may not run in the particular sequence you'd like. And finally, since all the work is done for you, this is the most costly way to acquire software.

The second approach is to buy a book that contains listings (printouts) of astronomy programs. You then sit at your machine and key the programs in, one line at a time, saving them on your floppy disk or tape. Usually, the programs you find in these books are written in BASIC, a common computer language. As with human languages, however, there are slight differences between each computer's version of BASIC so that, in effect, each machine has its own "dialect." The version printed in the book will probably differ from that used by your machine. In this case, you need to translate the printed version into the appropriate dialect to run on your machine. This sounds more fearsome than it is and the exercise will greatly increase your BASIC programming skills — a good idea in any case.

Which leads to the third alternative: writing the programs from scratch yourself. This is really the best way to build a software library of astronomy programs. While printed programs are generally good, there is no better way to satisfy your exact needs and desires than to write your own programs — after all, the essence of a computer's usefulness lies in custom-tailoring the results to your wishes. Of course, learning BASIC does take a little time and effort but as the name implies, it's quite easy. (Come on, anything a 12-year-old can learn, you can, too!)

If the thought of learning BASIC from the manuals supplied with your computer scares you, then check out the classes that most good computer stores now offer. Community colleges, university extension services, and high schools are offering night, weekend, or correspondence courses, also. Anyone who wants programming skills can usually obtain them quite easily today.

The astronomy enthusiast who knows how to program his computer himself has opened up a vast new world to the power of his machine. Computers are unbelievably fast and efficient "number-crunchers," enabling you to do things at home that even the professionals couldn't do just a decade ago. But do-it-yourself programming is the key.

Let's now examine some of the things you can do with a home computer. There are three major areas where it can assist you: number-crunching, data base management, and station-keeping.

Number-Crunching

If nothing else, the computer gives you a sobering look at the complexities involved in astronomical calculations. It enables you to explore a region where just a decade ago only the most dedicated and courageous amateurs dared venture. And it allows quick and relatively painless looks at many different alternatives. But as with calculators before it, the computer does not eliminate your need to *understand* a problem, though it does eliminate the tedious hours of math involved in working it through.

With this new power comes a responsibility for learning correct methods and using proper reference materials. You'll find yourself delving into such information gold mines as the *Astronomical Almanac* (or its offshoot the *Almanac for Computers*), star catalogs, charts, and dozens of other books and publications. In this sense the computer becomes a driving force behind a whole new dimension in learning for you.

As you begin to assemble a software library, you may create programs that yield sidereal, Greenwich, and local time unique to your location. You can calculate sunrise, sunset, ephemerides of planets or locations of any observable body in the solar system, given parabolic, elliptical, or other orbital elements. Precession, stellar masses, or binary star orbits are also within the range of small computers. Programs are even available to view star locations at any time in the past or future, or from any location inside or out of the Milky Way Galaxy.

If you're interested in stellar photometry, you may determine atmospheric extinction corrections, calibrations, and analyze variable star periods. Astrophotographers can calculate exposure times for the Moon, planets, or stars, given phase, filters, or magnitude differences. The computer's untiring energy lets it handle any of these long and difficult or iterative calculations quickly and without error.

Data Base Management

With the naked eye we can easily see thousands of stars. Astronomers tell us that in the Milky Way alone there are about 3×10^{11} stars. We have given common names to over 200 of these and numbers to hundreds of thousands more. The computer's flawless memory and remarkable capacity to relate pieces of information can help you create a file on these stars and keep track of them along with all the information associated with each. Such a set of facts is called a data base.

To illustrate how powerful a machine can be that manipulates a data base, consider NASA's "SKYMAP." This mammoth data base contains records on 248,727 stars down to ninth magnitude and has over 100 different pieces of information on each star. A printout of the entire data base would run to over 20,000 pages printed both sides in standard-size type. If bound, the volume would be over 11 feet thick. It is clearly impossible to go into this data base by hand and try to summarize any given set of characteristics. At the moment, you, as a home computer owner, do not have access to the SKYMAP data base — but you probably will within five years when billion-byte video-storage units are available.

For the present you can develop data bases to suit your own personal observing interests. For example, if you specialize in observing galaxies, you can easily create a data base, entering the name, position, magnitude, comments, and other pieces of information about what you observe. Then you can call up all galaxies of a certain type or those with a given set of characteristics from the data base.

All the information to go into your data base — keyed in on cloudy nights — probably exists already scattered among sundry atlases, catalogs, observing guides, and the like. But the beauty of having your own data base is that you can select from this bewildering swarm of information only those facts you want to include and gather them all in one place, updating it as frequently as necessary. In the end, you will not only end up with a custom-built treasury of information, but will have it in the computer, where you can manipulate it in an endless variety of ways.

Station-Keeping

Station-keeping is a fancy catch-all term for such mundane functions as maintaining a log book, word processing, and displaying results in a graphic form. It all sounds sort of dull at first, but when you realize this can *show* you where the jovian moons are in their orbits, or illustrate the magnitudes and positions of selected stars, or display precession motions — then the possibilities become exciting.

Multi-color chart plotters are now available for under $1,000. They can draw variable star magnitude changes or the orbits of Saturn's moons — or display the passage of a radio source through an antenna array. You need only collect the data manually and enter it into the computer. (In the last-mentioned case, an ambitious observer could rig up a system that stores the information electronically as it is picked up by the receiver.)

Log-keeping is another valuable function. Say you enter the records of your observations directly into the computer. You can then scan through the entire record (or just parts of it) for specific references to objects and call up the records in any sequence you like. Linked to a data base, your log "book" then becomes a powerful manipulative tool for storing, recalling, comparing, and evaluating all your observing notes and information.

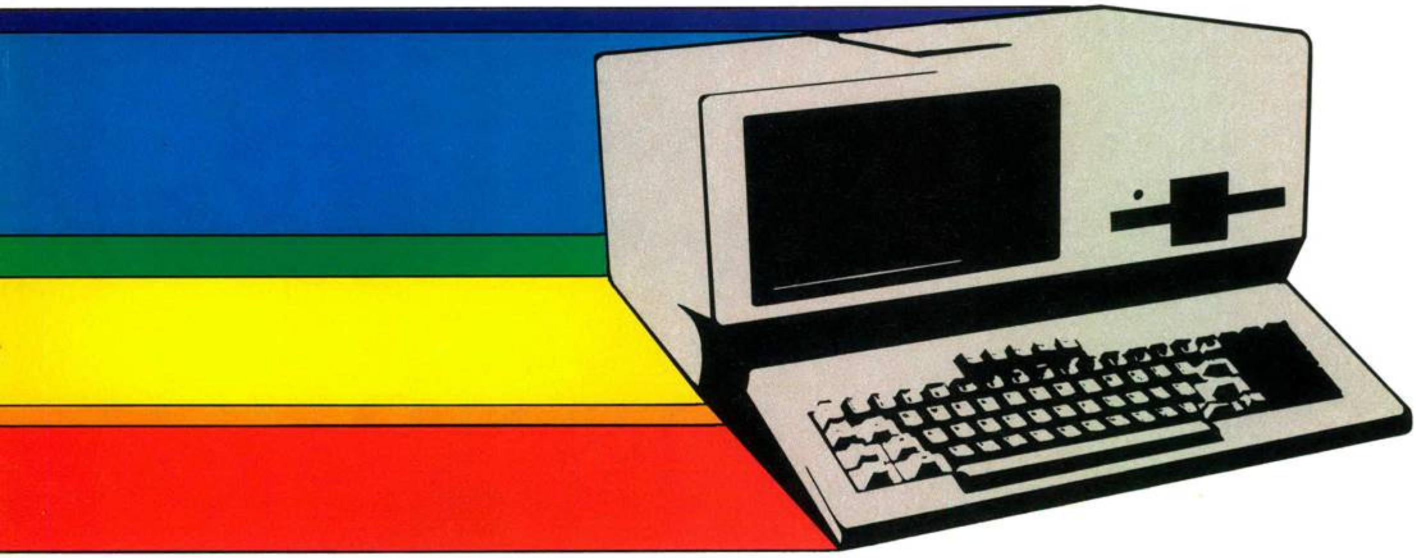
Finally, word processing software lets you or your club crank out reports for a "smooth" log or for the club's newsletter — and it is likely to be useful in other parts of your daily life as well.

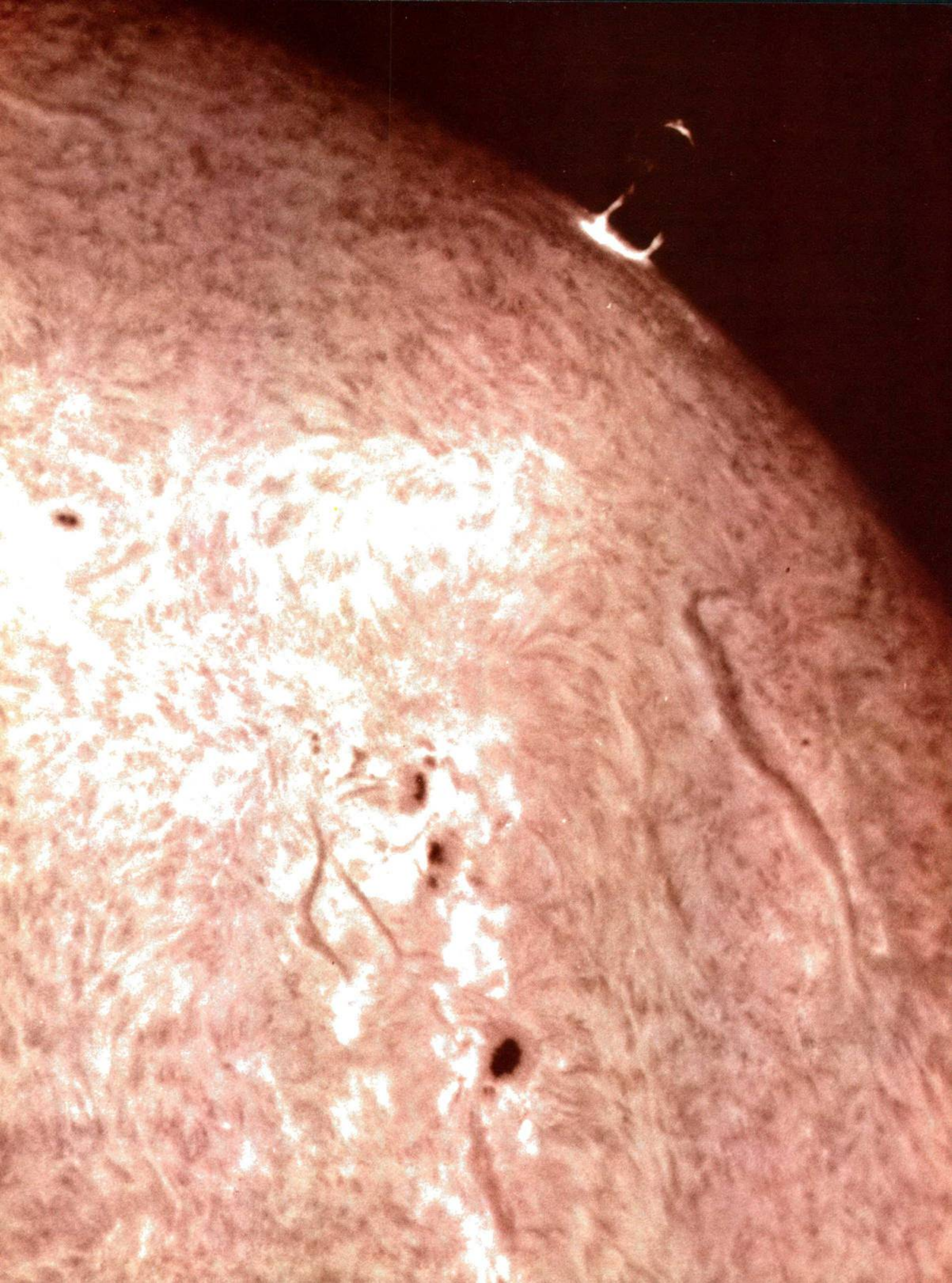
Evolution of Amateur Astronomy

The small computer is burrowing its way into every aspect of our lives, and it's only natural that it should appear in the backyard observatory as well. With adequate planning and forethought, an amateur astronomer can have a very powerful "observing assistant" under fingertip control. Gigabyte (billion character) storage is just around the corner; NASA's SKYMAP may soon be accessible to everyone. Advances are coming quickly, and it is probably inevitable that one fine day the backyard telescope itself will be supplanted by a supersensitive electronic photon accumulator that will beam high-resolution images to your computer monitor.

Sounds wacky, doesn't it? Well, maybe none of us would ever want to do that anyway. But the future is here at our fingertips, right now. It's exciting to flash through astronomical data bases, and there's quite a thrill in calling up Io's orbital position on the computer monitor and then going outside to see it for real in the eyepiece of the telescope, just as predicted. Astronomy and computers share a natural affinity, and no wonder — both deal with tiny detail and keep an eye for the infinite. Ptolemy would have thought them magic, and at times I'm not so sure I don't, too!

Dennis W. Chamberland is a freelance science writer. A computer hobbyist as well as an amateur astronomer, he combines his hobbies by developing personal astronomy data bases and programs.





the backyard astronomer

scutum and serpens cauda

Mercury

On the last day of July, Mercury will pass close to Aldebaran, α Tauri, in the Hyades cluster. Unfortunately, the planet will be low in the west, and you'll have to squeeze your observations into the interval between when the sky becomes dark and when the planet sets.

Mercury will reach greatest elongation on August 19th, some 27° east of the Sun. Although the angular separation is about the largest possible, the planet's visibility will be very poor. Your best opportunity to see it will be during the first week of August, when Mercury's elevation will be about 3° over the western horizon, 45 minutes after sundown.

Venus

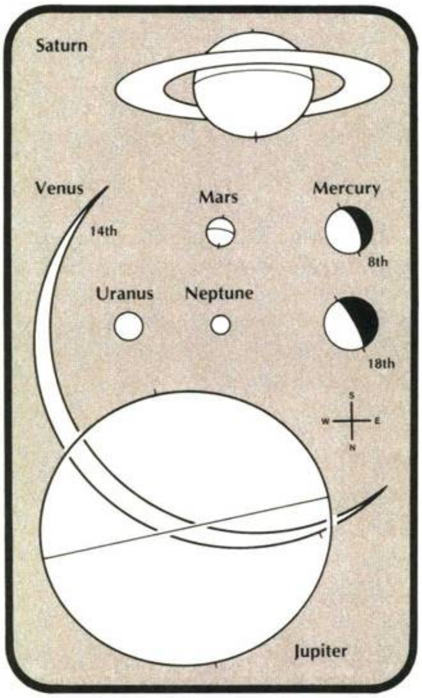
This month, Venus will pass from the evening into the morning sky, with inferior conjunction occurring on the 25th. Prior to that, you can catch sight of it in the evening sky soon after sunset; by the 31st, it will be visible in the east just before sunrise.

As Venus is 8° south of the Sun at inferior conjunction, you may wish to try observing it during daylight. Pick a day as clear and free from haze as possible, and center the Sun's disk in the eyepiece (using projection or an over-the-aperture filter). Then offset to locate the planet, remove the filter (if used), and look for Venus. The amounts to offset are tabulated in the box on page 82.

If you follow Venus through inferior conjunction, you'll see the extremely thin crescent of the disk swing from the western side through north to the eastern side as the planet passes between us and the Sun. In addition to the crescent, you may also see sunlight refracted through the planet's atmosphere to form a ghostly ring around the dark disk of the planet.

Mars

During August, as it passes eastward along the ecliptic out of Gemini and into Cancer, Mars rises earlier and earlier before the Sun. By the end of the month, 45 minutes before sunrise, it is some 15° high in the east-northeast. On the 24th and 25th, it will pass through M-44, the Beehive Cluster — your best views will be with low-power instruments (RFTs or binoculars).



Asteroids

1 Ceres (magnitude 7.5) is moving retrograde in Piscis Austrinus. Its positions:

9th: 21h 58m 22s, −27° 05.6′
19th: 21h 49m 42s, −28° 03.7′

Ceres is at opposition on the 14th and rises about 9 p.m. local daylight time on that date.

2 Pallas (9.7) lies in eastern Hercules and is moving almost due south. Its positions:

9th: 18h 26m 36s, +18° 13.2′
19th: 18h 23m 23s, +16° 20.6′

Pallas is visible during all the hours of darkness.

3 Juno (8.9) is moving eastward from Pisces into Cetus. Its positions:

9th: 1h 58m 57s, +8° 00.0′
19th: 2h 09m 21s, +7° 33.6′

Juno rises around midnight local daylight time on the 15th.

4 Vesta (8.3) lies in Taurus, having passed Aldebaran on the 31st of July. Its positions:

9th: 4h 49m 00s, +17° 20.8′
19th: 5h 02m 48s, +17° 39.6′

Vesta rises about 2 a.m. local daylight time at mid-month.

To facilitate plotting their positions on a star atlas, all asteroid coordinates are for the epoch 2000.0.

Jupiter

Jupiter's motion during August takes it eastward toward the double star Beta (β) Scorpii. It will pass a degree and a half south of the star on September 3rd.

As Jupiter becomes more of an evening object, it will set earlier and earlier. Although you'll be able to observe it for about three months more, the end of this year's apparition is already in sight.

Saturn

This month, Saturn's visibility will noticeably diminish. As the month opens, it can be clearly seen about 30° high in the southwest soon after sunset, but by month's end, it will be at half that elevation. Get in your observations while you can — by the end of next month, it will be too low for useful telescopic observations.

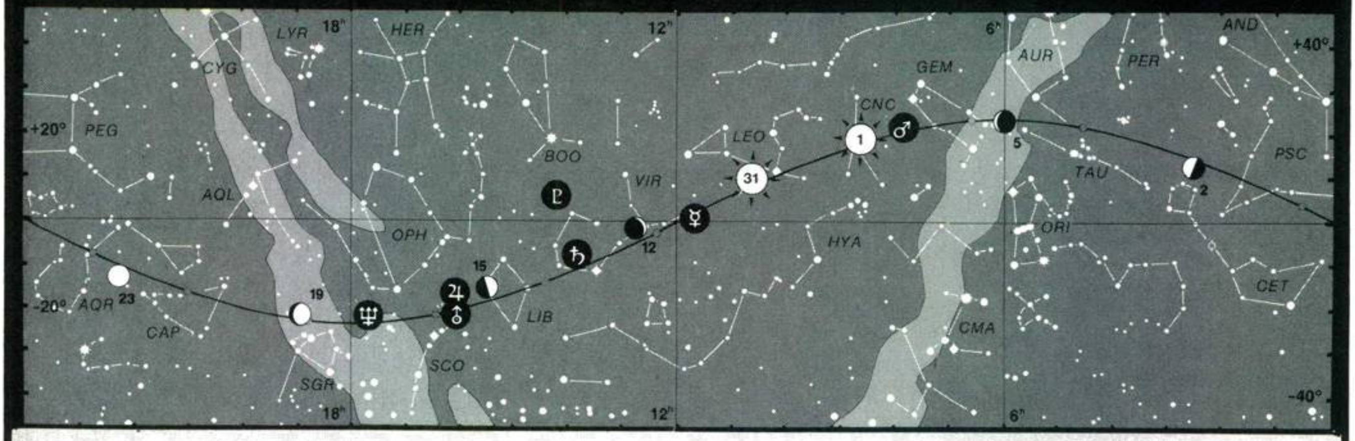
Uranus

Locating Uranus is pretty easy: first

Randy Tatum's photo of the Sun in Hα — August's "Best Astro-Photo" — was taken with a 7-inch refractor stopped to 3½ inches, a 0.7 Angstrom filter, an effective focal ratio of f/30, and 2415 film. Note the dark sunspots, the granulation, and the dusky streaks of prominences seen in silhouette.

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

planetary data august 1983


LYR
18h
HER
12h
6h
AND
+40°
CYG
GEM
AUR
PER
CNC
1
♂
5
+20°
PEG
LEO
31
BOO
TAU
PSC
2
♇
VIR
AQL
☿
OPH
12
HYA
ORI
♄
15
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♅
19
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-20°
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23
CAP
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CMA
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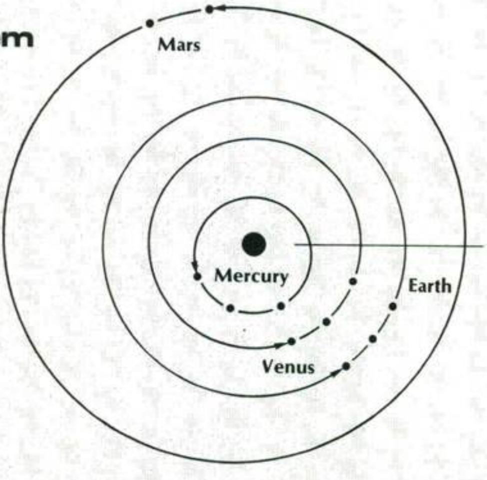
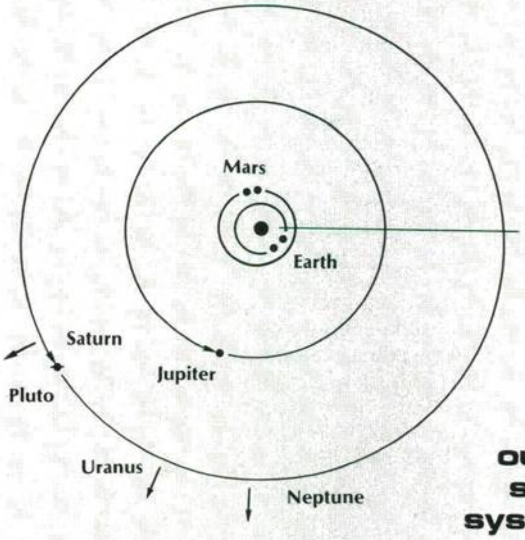
SGR
18h
12h
6h
-40°

inner solar system


Mars
Mercury
Earth
Venus


Mars
Earth
Saturn
Pluto
Jupiter
Uranus
Neptune

outer solar system

		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (1983.7)	Dec.
Sun		1	−26.7	31.6′	—	1.02	—	—	128°12.4′	8h 42.5m	+18°13.1′
		15	−26.7	31.6′	—	1.01	—	—	141°37.7′	9h 36.0m	+14°18.0′
		31	−26.7	31.7′	—	1.01	—	—	157°02.5′	10h 35.0m	+ 8°55.8′
Mercury	☿	1	−0.1	5.7″	76%	1.17	0.43	208°06.0′	148°46.8′	10h 07.0m	+12°32.4′
		15	+0.4	6.8″	58%	0.98	0.47	249°10.4′	161°52.0′	11h 16.0m	+ 3°25.4′
		31	+0.9	8.9″	30%	0.75	0.44	294°33.2′	179°46.1′	11h 55.8m	− 3°41.0′
Venus	♀	10	−3.8	52.4″	8%	0.32	0.73	307°23.7′	157°49.2′	10h 32.5m	+ 2°44.2′
		31	−3.4	57.6″	2%	0.29	0.73	340°38.6′	147°38.3′	9h 48.8m	+ 4°14.8′
Mars	♂	15	+1.9	3.7″	99%	2.52	1.61	107°57.7′	120°22.2′	8h 13.1m	+20°57.5′
Jupiter	♃	15	−1.8	38.9″	99%	5.06	5.33	252°17.3′	241°02.4′	15h 58.1m	−19°49.7′
Saturn	♄	15	+0.9	16.4″	100%	10.14	9.80	214°47.8′	208°50.5′	13h 52.3m	−9°01.2′
Uranus	♅	15	+5.9	3.7″	100%	18.70	18.96	248°03.1′	244°37.3′	16h 12.6m	−21°04.0′
Neptune	♆	15	+7.7	2.5″	100%	29.67	30.27	268°11.7′	266°09.9′	17h 45.4m	−22°09.4′
Pluto	♇	15	+13.9	0.1″	100%	30.26	29.87	209°59.2′	206°40.5′	14h 04.6m	+ 5°10.4′

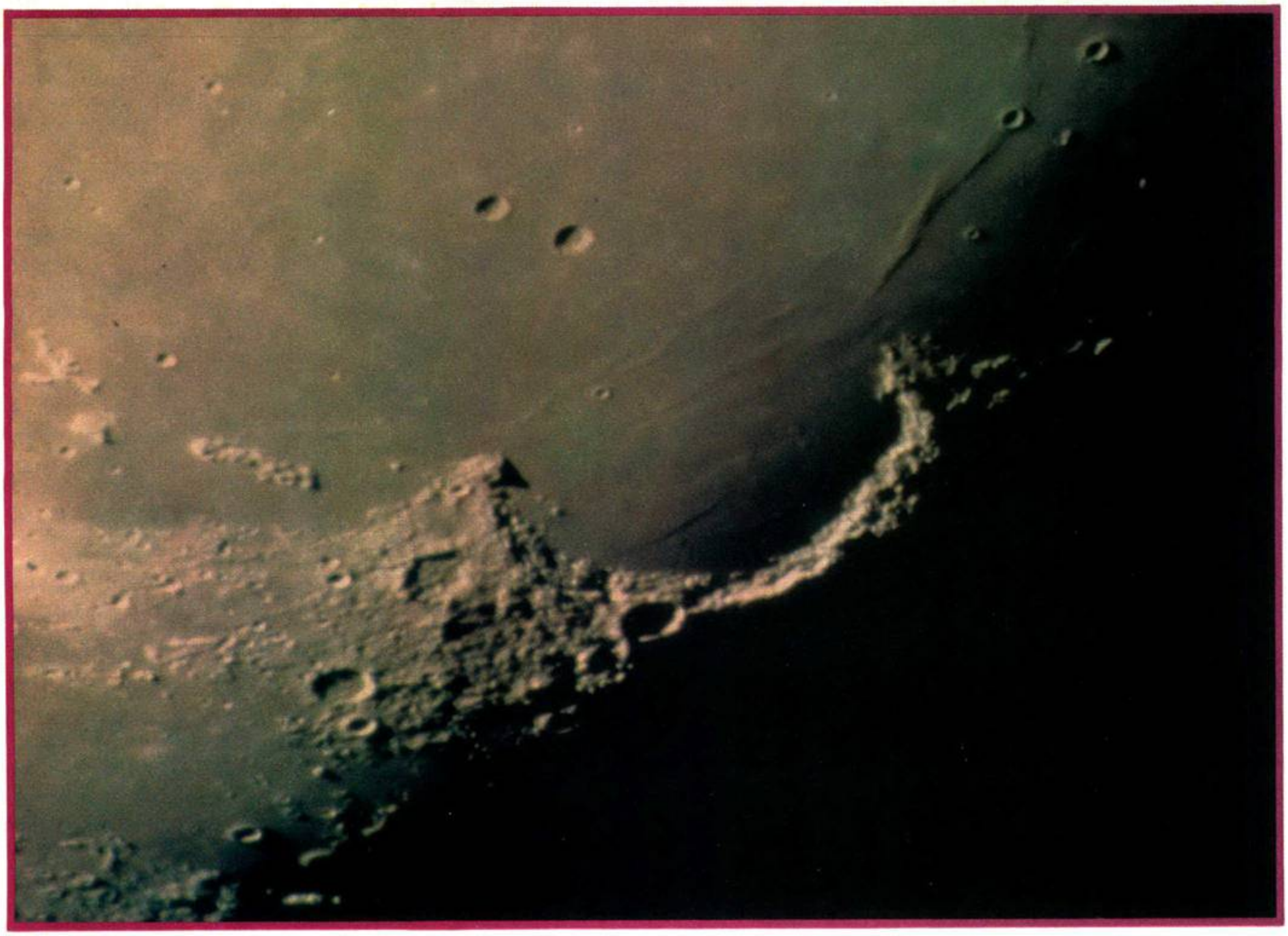
moon data

Last Quarter	August 2 at 00:52
New Moon	August 8 at 19:18
First Quarter	August 15 at 12:47
Full Moon	August 23 at 14:59
Last Quarter	August 31 at 11:22
New Moon	September 7 at 2:35

Perigee: August 8 at 19:30 . . . 357,175 km.
Apogee: August 22 at 9:27 . . . 406,276 km.

universal time

Astronomers the world over use an unambiguous system of time reckoning — Universal Time (UT) — based on a 24 hour clock. Times given in The Backyard Astronomer are UT unless noted otherwise. To convert UT into your local daylight time, subtract the following number of hours for each time zone: EDT, 4; CDT, 5: MDT, 6; PDT, 7; Alaska, 9. For example, if an event is to happen at 03:00 hours UT on June 7, then EDT for the event is 11 p.m., June 6. Likewise, 03:00 UT on September 2 becomes, in PDT, 8 p.m., September 1.



Curving deeply into the Jura Mountains in the northwestern part of Mare Imbrium, Sinus Iridum — the Bay of Rainbows — is a crater whose "seaward" wall has been breached, flooding its floor with mare basalts. Jean Dragesco's photo (taken with a 14-inch SCT and 200 ASA film) shows the Bay lit by the rising Sun.

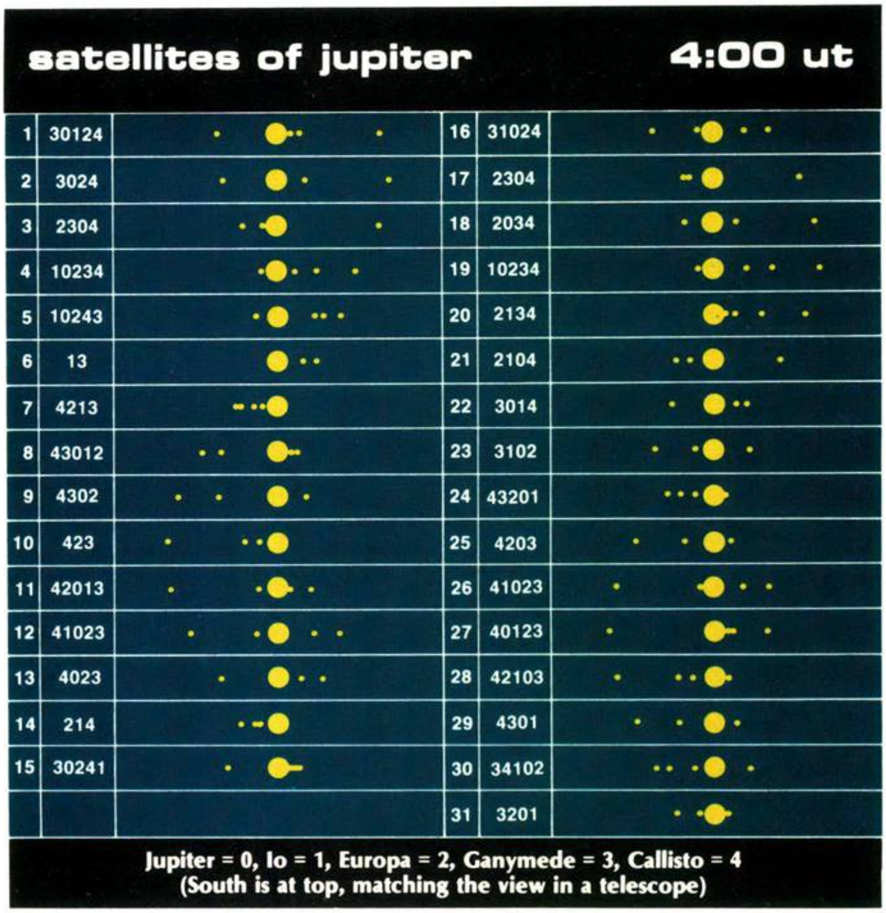
center your scope on Jupiter, then offset it about 1° 15′ to the south and slowly sweep eastward some 10 to 15 minutes of right ascension. Uranus is recognizable by its 3.7″ of arc disk, which glows softly at 5.9 magnitude.

Neptune

To find Neptune, swing your scope (equipped with a low-power eyepiece) into the heart of the Milky Way in Sagittarius. Once there, center M-20, the Trifid Nebula, in your eyepiece. Now shift your scope a degree north and sweep it westward a distance of about 15 minutes of r.a.; Neptune should be in the field of view, showing a 7.7 magnitude disk, 2.5″ of arc across. Higher powers will probably be necessary if you want to make out the disk clearly.

Meteors

August is Perseid month, and this year's display on the night of August 12-13 promises to be one of the best. Fortunately, the Moon will set early that night, leaving the sky dark as the radiant point — near the Double Cluster — climbs



satellites of jupiter **4:00 ut**

1	30124	16	31024
2	3024	17	2304
3	2304	18	2034
4	10234	19	10234
5	10243	20	2134
6	13	21	2104
7	4213	22	3014
8	43012	23	3102
9	4302	24	43201
10	423	25	4203
11	42013	26	41023
12	41023	27	40123
13	4023	28	42103
14	214	29	4301
15	30241	30	34102
		31	3201

Jupiter = 0, Io = 1, Europa = 2, Ganymede = 3, Callisto = 4
(South is at top, matching the view in a telescope)

Left: M-13 may be the finest globular cluster visible from mid-northern latitudes — Orion Ernest took its photo using 400 ASA film, a cold camera, and a 30-minute exposure with an 8-inch f/5 Newtonian. Right: John Gleason's Trifid Nebula was taken with an 8-inch SCT at f/10 and a 45-minute exposure on 200 ASA film.

higher into the sky. Due to the possibly imminent return of the parent comet of this swarm, Comet Swift-Tuttle (see the feature article starting on page 16), the number of meteors per hour has increased greatly in the past few years. From a dark-sky location in the wee hours of the 13th, you can expect to see some 60 to 100 per hour — and even more if you're lucky. Don't miss it!

close-up on scutum and serpens cauda

This month we look at not one but two constellations, located side by side in the rich summer Milky Way. **Serpens Cauda**, the Serpent's Tail, lies next to **Scutum** the Shield just north of the cluttered Sagittarius area. (Serpens Caput, the Serpent's Head, which comprises the other half of Serpens, lies on the western side of Ophiuchus.) Both Serpens Cauda and Scutum are rich in Milky Way objects, chiefly open and globular clusters.

The most commanding object in Serpens Cauda is the huge open cluster **IC 4756**. This giant group contains 80 stars of seventh magnitude and fainter, scattered over an area 70′ of arc in diameter. Thus it is one of the largest open star clusters in the sky and is best observed with finderscopes and binoculars. Even a low-power eyepiece on short focal length telescopes doesn't contain the entire assemblage. If you have large binoculars such as 11x80s, you'll come away with the best possible view.

Sun-Venus Offsetting

	R.A.	Dec.
Aug. 20	19m 41s E	10°09′S
21	13m 39s	9°44′
22	7m 35s	9°18′
23	1m 30s	8°51′
24	4m 36s W	8°23′
25	10m 40s	7°54′
26	16m 45s	7°24′
27	22m 46s	6°52′
28	28m 45s	6°21′
29	34m 40s	5°48′
30	40m 30s	5°15′

(direction is *from* Sun *to* Venus)

The other bright cluster in Serpens Cauda is **M-16**, an extended region of emission nebulosity and associated young stars. This is the famous Eagle Nebula, named for its resemblance to an eagle in long-exposure photos. The nebulosity is difficult to see due to its low surface brightness, but a 4-inch scope can pick it up on dark nights. The view through progressively larger apertures doesn't improve drastically: even in a 12-inch scope the nebulosity appears as a general haze superimposed on the grouping of stars. In 6-inch and larger scopes, however, you'll be able to detect some of the dark nebulosity that cuts in front of the bright haze. M-16 contains about 60 stars of magnitude 8 and fainter. The cluster alone is a rewarding sight in binoculars and small telescopes.

Just 30′ northwest of M-16 is another cluster, **H19**. This little group of suns holds 40 members fainter than 11th magnitude, compressed into an area only 5′ across. If you have a large scope — 12 to 20 inches in diameter — aim it at this cluster, using high magnification. The view should be quite pleasing.

Two tiny globular clusters lie on the boundaries of Serpens Cauda — **NGC-6535** and **NGC-6539**. Neither is particularly impressive in small aperture scopes: 6535 shines at 11th magnitude and measures 1.5′ across, while 6539 is slightly larger but fainter (12th magnitude, 2.5′ diameter). A good 3-inch telescope should show these objects, but they'll look like tiny, fuzzy stars. Try at least a 6-incher at about 125x — each cluster appears as a hazy ball of light, perhaps showing a slight central condensation.

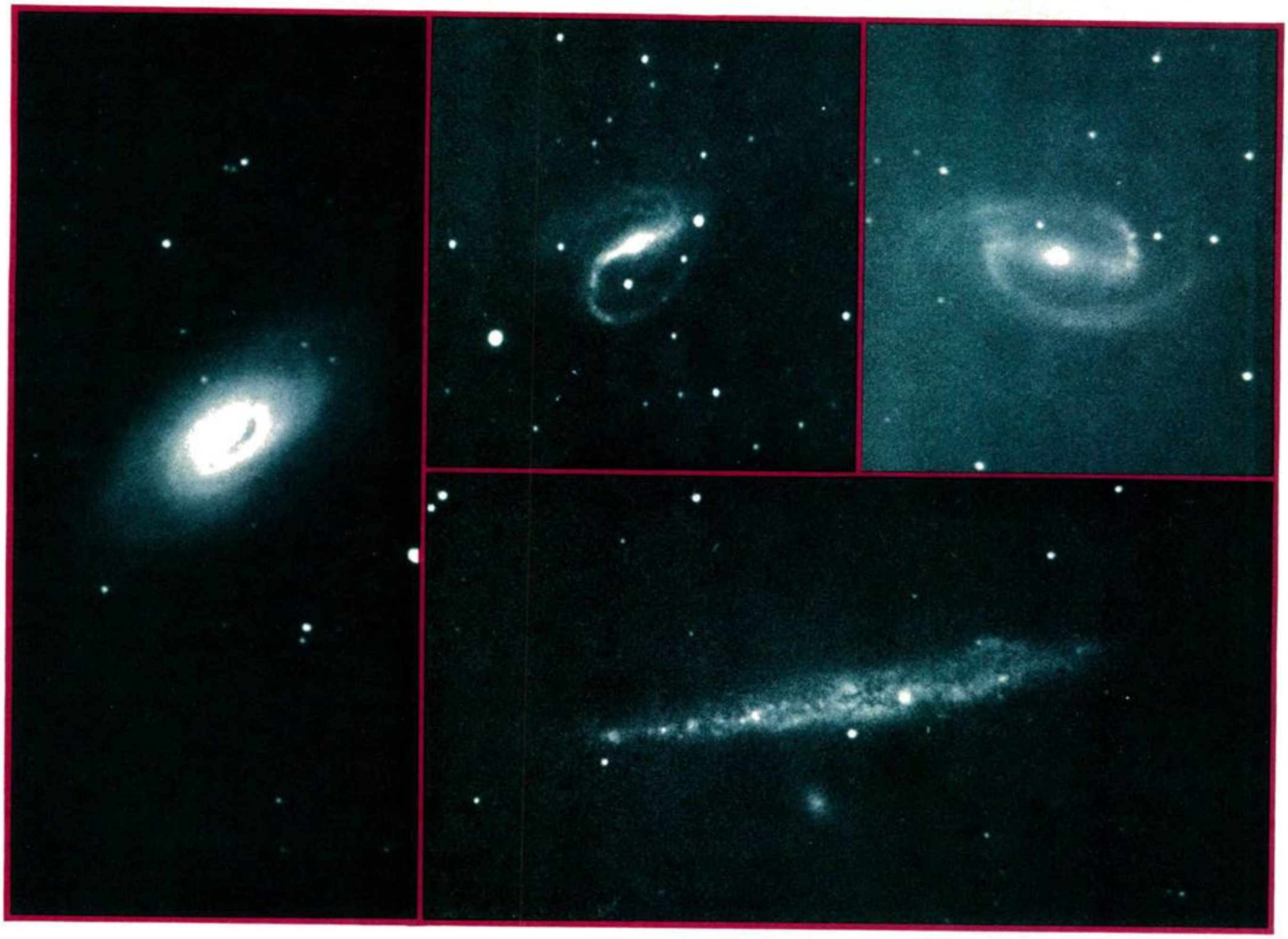
Serpens Cauda holds a number of stars worth watching. One is the bright double **Theta** (*θ*) **Serpentis**, a wide binary consisting of magnitude 4.5 and 5 suns. The two stars are separated by some 22″, so binoculars and small scopes can split them. Both stars show a pale yellowish tint. They lie at a distance of about 130 light-years, so the actual distance between the two is approximately 900 astronomical units.

A remarkable star in the constellation is the eclipsing binary **W Serpentis**, about 3° southwest of M-16. This unusual object fluctuates between magnitudes 8.9 and 10.3 over a period of about 14 days. W Ser displays an odd light curve, suggesting to astronomers that it may be a unique type of eclipsing variable, or that it may not truly be a system that varies in brightness due to eclipses by a component star. But in lieu of a better explanation, the best model suggests that there are two stars — one 6 and the other 8 times the mass of the Sun — separated by a gap of 14 million miles.

Another unusual variable star lies across the border in Scutum. **R Scuti** is a semi-regular pulsating variable found 1° south of Beta (*β*) Scuti. This reddish star varies between magnitudes 4.8 and 6.0, sometimes dipping down to magnitude 8 or fainter, over a period of 140 days. R Sct shows characteristic signs of both Cepheids and Long Period Variables, but with its own individual quirks. It is a huge star — some 100 times the size of the Sun — and probably contains 25 times as much matter as Sol. At peak luminosity R Sct is a blazing inferno, emitting 8,000 times as much light as the Sun. Its distance from Earth is difficult to pin down due to interstellar absorption, but is probably around 3,000 light-years.

Just 1° southeast of R Sct is the famous open cluster **M-11**, referred to as the "Wild Duck Cluster" because of its triangular shape, which according to many observers resembles a flock of ducks in flight. One of the most stunning Messier objects, M-11 is easily observed in binoculars or any telescope. Using low powers on this object, you'll see the triangular shape formed by 500 stars of 11th to 14th magnitude. Because the group contains so many stars in an area 12′ across, you can use high powers for an exceptional view on nights of good seeing.

M-11 lies 5,500 light-years away,



Left: M-64, the "Black-Eye" galaxy; photo by Paul Roques (8-inch SCT, f/5, hypered 2415). Top: Two barred spirals, NGC-7479 and NGC-1300, photographed by David Healy (14-inch SCT, f/6, hypered 2415, 45 minutes for 7479, 60 for 1300). Above: NGC-4631 by Martin Germano (8-inch SCT, f/10, 103a-F, 70 minutes).

making its true diameter about 15 light-years. Were the Sun placed at this distance, it would glow faintly at 16th magnitude. This makes it easy to understand that the brightest stars in M-11 are very luminous giants: they radiate with the intensity of 100 suns. It is a middle-aged cluster, probably about 500 million years old, and will gradually dissipate as it rotates around the galactic core. In 1932 Robert J. Trumpler calculated that if you stood on a planet circling a star in M-11, you would see a sky filled with several hundred first-magnitude suns, with perhaps a few dozen even brighter than Sirius!

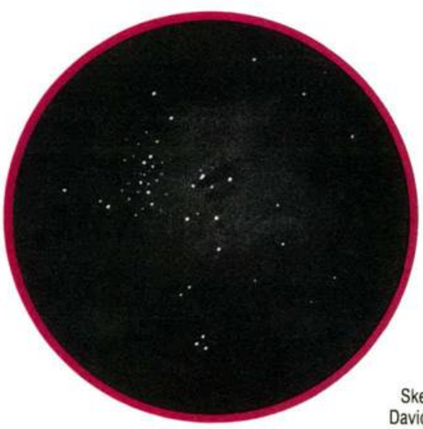
Two other notable open clusters in Scutum are **M-26** and **NGC-6704**. M-26 contains 25 stars between magnitudes 11 and 14 in a 9′ diameter — a fine sight in small telescopes. It lies at a distance of about 4,900 light-years, and measures about 12 light-years across. NGC-6704 is rich compared to M-26, packing 25 stars between magnitudes 12 and 14 into a 2′ diameter. On nights of good seeing, large telescopes at high powers show this group as a faint mottled haze, almost resembling a remote globular cluster.

The lone globular cluster in Scutum is the faint object **NGC-6712**, which shines through the Milky Way's dust at magnitude 9. Its constituent stars are 15th magnitude and fainter; in most telescopes, it looks like a fuzzy ball 3′ in diameter. Were it out of the way of the galactic core, NGC-6712 certainly would be a more interesting object in backyard telescopes. But try it out next time you're observing: this object may convince you that not *all* globular clusters look alike.

The constellations Serpens Cauda and Scutum are prime target areas for your summer observing. Together they contain clusters galore, unusual Milky Way stars, and one of the most intricate areas of emission nebulosity in the sky. And you don't even need a telescope to observe one of the finest showpieces of the region — the Scutum Starcloud. This huge, hazy, naked-eye glow represents the light from hundreds of thousands of stars, each one floating in the space between us and the center of the Galaxy.

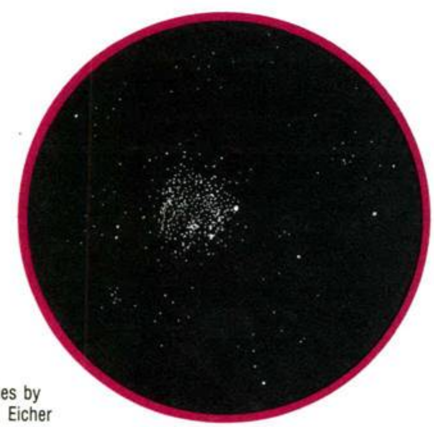
M-16

8-inch scope at 100x



M-11

8-inch scope at 70x

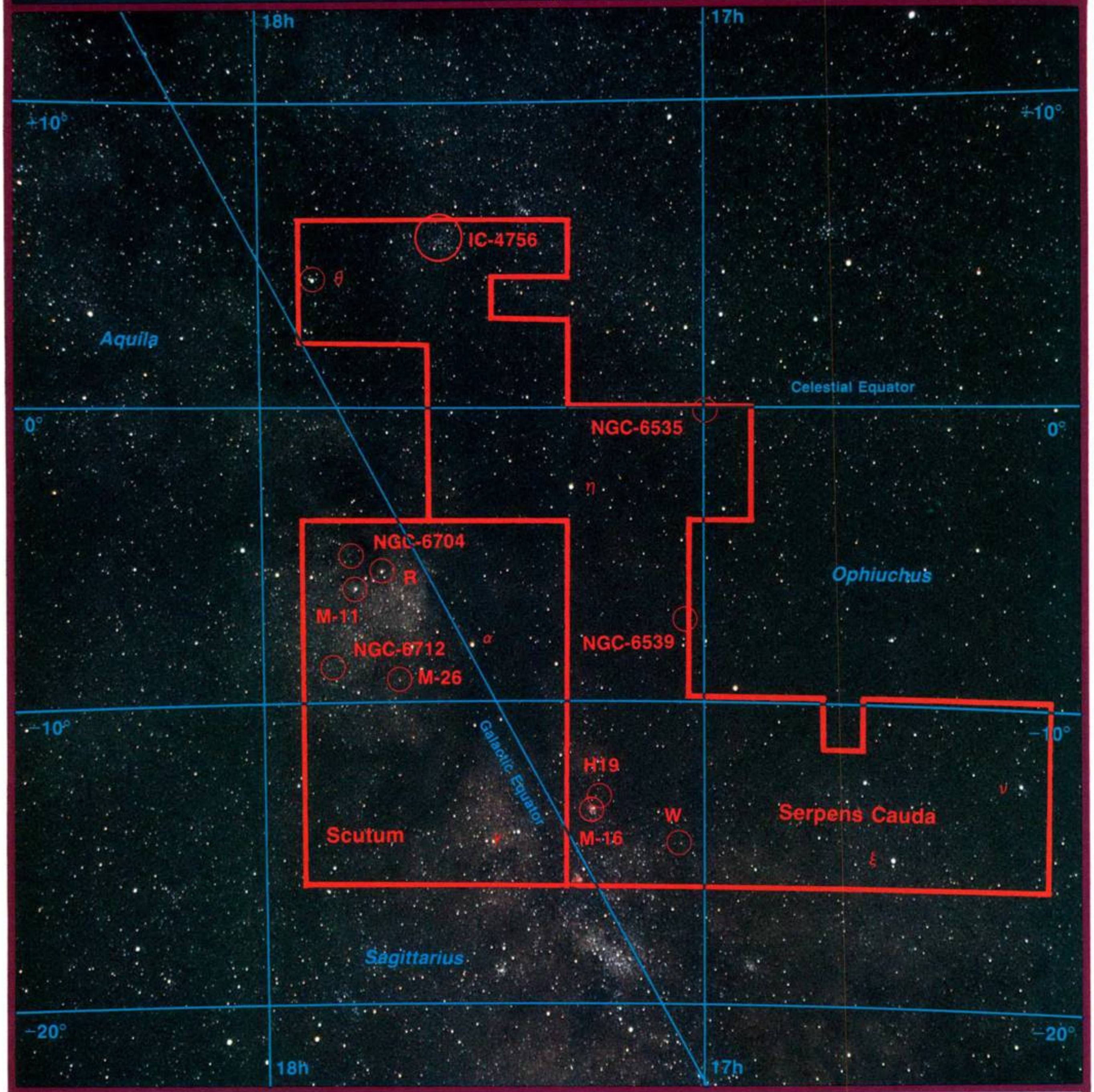


Sketches by
David J. Eicher

Map by
David J. Eicher

scutum/serpens cauda

Photo by Robert Provin
and Brad Wallis


18h
17h
+10°
+10°
IC-4756
θ
Aquila
Celestial Equator
0°
0°
NGC-6535
η
NGC-6704
R
Ophiuchus
M-11
NGC-6712
α
NGC-6539
M-26
−10°
−10°
Galactic Equator
H19
W
Serpens Cauda
ν
Scutum
M-16
ξ
Sagittarius
−20°
−20°
18h
17h

Object	Type	Mag.	Size/Sep. Per.	R.A. (1950) Dec.	R.A. (2000) Dec.
NGC-6535	●	11.0	1.5′	18h 01m −00°18′	18h 04m −00°18′
NGC-6539	●	12.0	2.5′	18h 02m −07°35′	18h 06m −07°35′
W Ser	EV	8.5→10.0	14.16d	18h 07m −15°34′	18h 10m −15°33′
H19	⊙	10.0	5.0′	18h 15m −13°18′	18h 17m −13°17′
M-16	⊙□	6.5	25.0	18h 16m −13°48′	18h 19m −13°47′
IC 4756	⊙	4.5	70.0′	18h 37m +05°26′	18h 39m +05°29′
M-26	⊙	9.5	9.0′	18h 42m −09°27′	18h 45m −09°24′
R Sct	SRV	4.9→8.2	140d	18h 44m −05°46′	18h 48m −05°43′
NGC-6704	⊙	9.5	2.0′	18h 48m −05°16′	18h 51m −05°12′
M-11	⊙	6.0	12,0′	18h 48m −06°20′	18h 51m −06°16′
NGC-6712	●	9.0	3.0′	18h 50m −08°47′	18h 53m −08°43′
θ Ser	★^{2}	4.5+5.0	22.2″	18h 54m +04°08′	18h 56m +04°12′

★	*Star*
★^{2}	*Double Star*
★^{3}	*Triple Star*
RV	*Regular Variable*
SRV	*Semi-Regular Variable*
IV	*Irregular Variable*
EV	*Eclipsing Variable*
⊙	*Open Cluster*
●	*Globular Cluster*
■	*Planetary Nebula*
□	*Bright Diffuse Nebula*
0	*Elliptical Galaxy*
§	*Spiral Galaxy*
∮	*Barred Spiral Galaxy*
#	*Peculiar/Irregular Galaxy*

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